Tax-Planning vs. Coordination:
The Dual Role of Internal Capital Allocation

by

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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

In this thesis, I examine how a multinational corporation (MNC) allocates capital among its international subsidiaries. This capital allocation has both a managerial and tax-planning objective. On the managerial side, it serves to coordinate collaboration between two subsidiaries on an innovative opportunity. Because subsidiaries in different jurisdictions have different tax rates, this capital allocation also plays a role in international tax-planning. An analytical model reveals that the MNC trades off the benefits of collaboration on the innovative opportunity against the tax cost associated with doing do. I further examine the implication of this tradeoff on how an MNC changes its capital allocation in response to a tax cut. The model provides a counter-intuitive result that an MNC does not always increase the amount of capital allocated to the country giving a tax cut. This thesis contributes to our understanding of the interaction between the managerial and tax decisions of MNCs. It does so by studying the interaction in the context of the flow of subsidiary-specific intangible resources rather than the flow of physical goods. This thesis has implications for both managerial practices and tax policies. While the tax-rate differential between subsidiaries provides tax-planning opportunities, it also creates a coordination cost that is external to the organization. Finally, the results from this model highlight the importance of considering the interconnectedness of an MNC in assessing the effect of a tax policy.

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Dedication

This thesis is dedicated to my husband Boyu Li and my loving parents Feng Xia Li and Lu Xing.

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Chapter 1. Introduction

The international landscape that multinational corporations (MNCs) operate in creates unique opportunities and challenges. On the managerial side, by operating in different countries and environments, the subsidiaries of MNCs develop a unique set of expertise and capabilities that together provide the MNC unique comparative advantages. However, these opportunities also present challenges in the management of the capabilities that are dispersed across different subsidiaries. As a result, the ability of the headquarters to coordinate across subsidiaries plays a crucial role in the successful execution of a business strategy. On the taxation side, MNCs can access different tax rules and rates that create unique tax-planning opportunities. However, the tax-rate differential between subsidiaries can also introduce a coordination cost that is external to the organization. In this thesis, I study how a central allocation of capital from the headquarters can coordinate the contribution of subsidiary-specific expertise in collaboration on an innovative opportunity. This capital allocation decision also has a tax-planning objective, and I study the tradeoff between the two objectives of the capital allocation decision. I also study the tax policy implication of this tradeoff by examining an MNC's capital allocation changes after a tax cut.

Early theory in international business regarded a multinational corporation (MNC) as a hierarchy where there is a well-defined vertical flow of responsibilities, with formalized and tight control from the top (Williamson 1985, Chandler 1962). Although there is a delegation of local responsibilities, no lateral interactions occur among subsidiaries. However, as businesses grow globally, the interdependence among internal parties increases, and new theory has emerged to address the complexity in subsidiary relationships. Recent studies in business strategy emphasize the horizontal dependence and lateral relationships that international subsidiaries form with one another. As a result, the network view has become a widely accepted theory in modern international business. Under this view, each subsidiary has a unique set of capabilities and expertise that serves its unique strategic role in its internal and external relationships, and the MNC forms new competitive advantages through accessing, connecting, and combining the capabilities that are dispersed across subsidiaries.

Within these networks that are interconnected through subsidiaries, coordinating resources is an important task (Barney 1991, Barney 2001, Peng 2001, Sirmon et al. 2011). Among the different types of resources, knowledge is the most important for forming new competencies through innovation (Gupta and Govindarajan 2000, Porter 1986, Teece 1981, Zander and Kogut 1995, Spender and Grant 1996, Simonin 1997), yet it is the most difficult to coordinate and manage across subsidiaries. First, subsidiaries often develop a new expertise and gain a strategic mandate through their own initiatives. Therefore, the headquarters does not have direct control over these specialized capabilities and expertise. Second, technical know-how, expertise, and experiences are tacit and non-transactable (Teece 1977, Szulanski 1996, Subramaniam and Venkatraman 2001, Dierickx and Cool 1989). Therefore, it is difficult to draft a formal contract with a subsidiary for providing its knowledge and intellectual input. Instead, identifying and providing opportunities for subsidiaries to work together on a common project and fostering lateral relationships are more effective ways to facilitate knowledge-sharing.

The international operations of MNCs not only unlock unique business opportunities but also unlock unique tax-planning opportunities through different sets of tax rules and tax rates. Most studies in international tax focus on vertical relationships between two subsidiaries and do not address subsidiaries' choices in forming lateral relationships. While a vertical relationship is appropriate to the traditional manufacturing setting where an upstream division supplies a well-defined product to a downstream division, it does not address the interdependence among subsidiaries governed by modern knowledge-driven business models. As described later in Chapter 2, recent studies have advanced our understanding on tax-planning strategies that involve intellectual property. However, these studies generally assume the headquarters' control over subsidiaries and do not discuss the coordination challenge that the headquarters faces in knowledge management. One exception to this is Johnson (2006) who studies the joint investment from two subsidiaries into an intellectual property, but her focus is on the physical investment rather than the intellectual input that each subsidiary makes. Furthermore, her setup concerns a sequential development and does not address the coordination among subsidiaries that must provide their input at the same time in a collaborative project.

In this thesis, I study the interaction between an MNC's tax-planning and its coordination of knowledge-sharing across subsidiaries. In Chapter 3, I present the base model setup where the two subsidiaries' choose to engage in a lateral collaboration with one another and study how capital allocation from the headquarters coordinates the choices by the subsidiaries. In my setup, the headquarters identifies an innovative opportunity that combines two areas of expertise within its knowledge network. Several studies find that although subsidiaries can be active in developing their own expertise, they are not necessarily aware of the resources available in other subsidiaries, so the headquarters plays an important role in identifying opportunities that connect the expertise from different subsidiaries to generate new competencies (Tallman and Koza 2010, Ambos and Mahnke 2010, Tran, Mahnke, and Ambos 2010, Birkinshaw, Hood, and Jonsson 1998).

The two types of expertise are held at two different subsidiaries that have full control over whether to contribute their expertise. The two subsidiaries are not pure research divisions, and they both have profit-generating production capabilities, so a subsidiary may choose to work on its own production instead of the collaborative project. If any subsidiary withholds its expertise, then the innovative opportunity cannot flourish. The need for coordination arises because even though the collaborative project is beneficial to the overall group profit, it may not be the best option for the subsidiaries. In my setup, the capital allocation from the headquarters between the two subsidiaries incentivizes them to provide their respective expertise. The coordination role of capital allocation is thus the effect of the central allocation of one type of resource (capital) on the coordination of another type of resource (subsidiary-specific knowledge). Furthermore, as is common in practice, the two international subsidiaries face different tax rates in their respective countries, allowing capital allocation to garner tax savings, and this is the tax-planning role of capital allocation.

In this context, the first-best solution refers to the scenario when there is no conflict between the coordination and the tax-planning role of capital allocation. In the first-best scenario, the optimal allocation can garner the maximum tax savings available while offering an incentive for the two subsidiaries to collaborate on the innovative project. Solving the model reveals that the first-best solution is achievable only if the innovative opportunity offers a very high return that is incremental to traditional processes. For example, the innovation's return must be at least twice the return of traditional processes to achieve the first-best solution, when the two subsidiaries have equal bargaining power and split the reward from collaborating on the innovative project equally. The exact threshold depends on the values of the parameters.

When the first-best solution is not achievable, the tax-minimizing allocation cannot incentivize both subsidiaries to undertake the innovative opportunity. Although the low-tax subsidiary is tax-favored, allocating too much capital to a subsidiary can prevent the two subsidiaries' collaboration. This is because the opportunity cost for investing in the innovative project increases with the amount of capital a subsidiary receives. In the extreme case when a subsidiary is allocated no capital, its opportunity cost for participating in the innovative project is zero. With nothing to lose, the subsidiary welcomes sharing the reward of the innovative project. In the other extreme case, when a subsidiary has all of the capital, its opportunity cost for participating in the innovative project is the full enjoyment of the profit it can earn from its own traditional production. Sharing the reward of the innovative project with the other subsidiary is no longer appealing in this case when it can do much better on its own. For this reason, the headquarters incurs a higher tax expense if it wishes to incentivize the two subsidiaries to both work on the innovative project.

Faced with a tradeoff between its tax-planning and its coordination objective, the headquarters must evaluate the benefit of the innovative opportunity against the tax cost associated with incentivizing the collaboration. If the incremental profitability of the innovative opportunity is not high enough to outweigh the cost, the headquarters optimally forgoes the opportunity and focuses only on tax savings. On the other hand, if the incremental profitability of the innovative opportunity is high enough to outweigh the cost, then the optimal allocation incentivizes collaboration with the lowest tax permissible.

In Chapter 4, I make several extensions to the base model. In particular, I introduce a prototype stage where the subsidiaries test out ideas and make a prototype product. Success during the early stages of an innovation process is crucial, but these early stages often consist of explorations with ill-defined objectives, making it difficult to manage. Prior studies have documented many ways in which prototyping can help in managing these early stages. First, the innovation team can experiment with different designs and learn more about the technical requirements. Second, by building a functional product, the innovation team is forced to turn conceptual ideas into executable plans. Finally, demonstrating the prototype to internal and external stakeholders helps boost confidence and support in addition to securing financing from internal and external sources.

The intellectual contribution from both subsidiaries of their respective expertise is critical to the success of the prototype for several reasons. First, cross-functional collaborations are an effective way for the innovation team to access the relevant expertise. Second, collaboration during the prototype stage provides an opportunity for the innovation team to contribute and discuss ideas early on, preventing costly interdepartmental disputes at a later stage. Third, cross-functional collaborations facilitate timely modifications and flexible use of the departmental resources. Finally, discussions that occur during these collaborations foster knowledge transfer and organizational learning.

I incorporate several features of the prototype stage into my model. First, to reflect the difficulties faced during the early stages of an innovative process, the prototype effort has a probability of failure. Second, to reflect the importance of the collective effort, the prototype cannot succeed unless both subsidiaries provide their respective expertise. Third, the subsidiaries are not required to make an investment decision until they have completed the prototype stage. The innovation process demands different types of resources during different stages. In the early development stage, the commitment of intellectual resources and expertise plays a more prominent role, whereas in the later production stage, it is the commitment of capital resources which plays a more prominent role.

Finally, the outcome of the prototype stage has an implication for the investment decisions. If the innovation team successfully demonstrates a functional prototype, then the innovation project is deemed to be a success that allows it to move along to the next stage, where the two subsidiaries make their investment choice with the capital allocated from the headquarters. Otherwise, the prototype is not considered a success, and the innovative opportunity is no longer suitable. In this case, the only investment opportunity left is the traditional process. From the headquarters' perspective, the observable outcome raises the question of whether it can improve its position by tying its capital allocation to the prototype outcome. I separately model the case when the headquarters uses the prototype outcome in its capital allocation and the case when the headquarters does not.

These model extensions provide three key insights. First, compared with the base model, incentivizing a subsidiary's intellectual contribution during the prototype stage faces the same issue that a subsidiary cannot be allocated too much capital. This is because each subsidiary's payoff depends on its investment decision at the later stage. If a subsidiary anticipates being allocated so much capital that it is better off working alone than sharing, then it will refuse to contribute intellectually during the prototype stage. Second, the tradeoff between coordinating the collaboration and the tax costs associated with it is like that in the base model. However, the threshold above which the tradeoff is worthwhile increases with the probability of failure. This is to offset the lower expected payoff on the innovative opportunity due to the probability of failure.

Finally, tying the capital allocation to the prototype outcome has advantages and disadvantages. The advantage is that it achieves a better expected payoff by allowing the headquarters to coordinate collaboration at a lower tax cost. However, because the capital allocation must incentivize both the intellectual contribution and the investment decision, the benefit is realized only if the headquarters can control the investment decision. On the other hand, tying the allocation to the prototype outcome means that the headquarters cannot allocate physical capital upfront. This presents a challenge for the headquarters to credibly commit to the allocation it originally specifies, even after observing the prototype has failed. When the subsidiaries perceive that the headquarters would favor the low-tax subsidiary after it has observed the prototype outcome, it becomes impossible for the headquarters to coordinate collaboration with any allocation, which is a disadvantage of not committing physical capital upfront.

In Chapter 5, I study the effect of certain tax policies on the subsidiaries' preferences toward the collaboration and the tradeoff that the headquarters faces between the tax-planning and the coordination objective in the capital allocation decision. I focus on tax policies that reduce the corporate tax rate that apply to all types of income (a general rate reduction) or specifically to innovation-related income (such as a "patent-box" regime). This reduction in tax rates is usually from high-tax countries that hope to stay competitive with their tax systems to attract investment and create employment opportunities (Clausing 2009, 2016, 2007, Desai, Foley, and Hines 2003). More recently, high-tax countries have become increasingly interested in attracting capital and activities specifically related to innovation, in response to the growing innovation economy. For example, the patent-box regime offers favorable tax treatments to innovations and has now been implemented by thirteen European countries and several others.[1] Although the details of implementation differ from country to country, the main highlight of all patent-box regimes is a drastic reduction of the tax rate applied to income derived from innovations (Böhm et al. 2015, Bradley, Dauchy, and Robinson 2015).

One of the most important stated policy objectives is to retain and attract capital investment, for both the general rate reduction and the patent-box regimes (Alstadsæter et al.

[1] Thirteen European countries have implemented the patent-box regime as of 2020. Outside Europe, China has implemented its version of the patent box regime, and lobbying effort and proposals continue circulating in both Canada and the U.S. For example, Quebec introduced a system that resembles the patent-box regime in 2017. https://www2.deloitte.com/content/dam/Deloitte/ca/Documents/tax/ca-en-RD-16-1-patent-box-AODA.PDF

2015, Bradley, Dauchy, and Robinson 2015, Chen et al. 2018, Schwab and Todtenhaupt 2019). To better understand the effect of these tax policies on capital allocation, I compare the MNC's optimal allocation before and after the policy change. I first study a general rate reduction where the country of the high-tax subsidiary reduces the tax rate applied to both the innovative opportunity and the traditional processes. I then study a specific rate reduction where the high-tax country reduces the tax rate, but only the innovative project qualifies. I study the effect both under the base model setup and with the extensions introduced in Chapter 4.

Contrary to conventional wisdom, an MNC does not always increase its capital allocation to the country that introduces a rate reduction. More specifically, I find that whether the MNC increases, decreases, or maintains its capital allocation to the high-tax subsidiary depends on how valuable internal collaboration is. In general, a tax cut has two effects, although the exact outcome varies depending on the model and whether the tax cut is general or specific. First, by narrowing the tax-rate differential between the two subsidiaries, it reduces the tax cost associated with the coordination. Therefore, an innovative opportunity may not be worth pursuing before the tax cut but becomes worth pursuing after the tax cut. In this case, the headquarters starts allocating capital to the high-tax subsidiary following the tax cut, and the capital allocation increases for the high-tax subsidiary. On the other hand, the innovative opportunity may still not be worth pursuing even after the tax cut, so the headquarters focuses only on the tax-minimizing objective, and the capital allocation does not change in this case.

The second effect of a tax cut is that it alleviates the incentive problem to collaborate on the innovative project. The tax cut enhances the appeal of collaborating on the innovative project for the low-tax subsidiary, by increasing the after-tax profit that the high-tax subsidiary can share. The headquarters can thus save more taxes while inducing collaboration, and in this case, the capital allocation decreases for the high-tax subsidiary. This counter-intuitive result highlights the importance of considering the internal coordination within an MNC’s network of internal knowledge-holders in assessing an MNC’s response to a certain tax incentive.

Comparing the specific rate reduction with the general rate reduction yields one additional insight. In the base model, the specific rate reduction has the exact same effect as the general rate reduction. This is because the two types of rate reduction change the headquarters’ tradeoff in the same way. Both the first and the second effects of the tax cut refer only to the tax rate applicable on the innovative project, which is a feature common to both rate reductions. On the other hand, in the model extensions, the benefit of the specific rate reduction is limited to successful innovations. As a result, the benefit from the specific rate reduction faces a risk of not being applicable, so its benefit is lower than that of the general rate reduction.

Chapter 2. Literature Review

2.1 International Tax Literature

By operating in multiple jurisdictions, multinational companies access not only different markets but also different sets of tax rules and tax rates. This presents international tax-planning opportunities that are unique to multinational corporations. In general, multinational companies have two types of tax-planning strategy. The first type shifts income that would otherwise be taxed in a high-tax jurisdiction to a low-tax jurisdiction without changing the underlying economics of the MNC's operation in these two jurisdictions, which is a strategy often referred in the literature as "paper shifting," "tax-motivated income-shifting," or simply "income-shifting." I use these terms interchangeably in this study. The second type incorporates the tax incentives into the firm's economic activities, which is a strategy referred as "real-shifting."

One important method to accomplish paper shifting is through setting internal transfer prices. A corporation that transacts between two legal entities within the corporate group needs to decide on the transfer between the two entities. Because this transfer price represents revenue for one entity and cost for the other, it essentially splits the pre-tax profit between the two parties. For tax purposes, the tax system taxes income based on where it is legally (rather than economically) earned, so the MNC has the incentive to create a transfer price such that it results in a higher profit to the entity located in the low-tax jurisdiction, within the limits set by the tax authorities regarding transfer-pricing rules.

In addition to transfer-pricing, many other techniques exist to accomplish paper shifting. For example, intra-company financing arrangements often allow interest expense deduction in the high-tax entity and interest-income tax in the low-tax entity. The transfer of intellectual properties is another common technique that allows for royalty deduction in the high-tax entity and royalty income tax in the low-tax entity. More aggressive strategies involve tapping into asymmetric tax treatments between two countries that result in no tax being paid in either jurisdiction. For example, a hybrid instrument can have its payment treated as an interest payment and deductible in one country, and at the same time treated as a dividend and non-taxable in another country (Johannesen 2014).

On the other hand, real-shifting entails allocating real assets and activities in low-tax jurisdictions, such that the economic income is taxed at lower tax rates. As discussed in the following subsections, the literature is rich with studies on paper shifting through transfer-pricing, but the area of real-shifting is underexplored. Due to concerns over aggressive paper shifting strategies, the Organization for Economic Co-operation and Development (OECD) launched the Base Erosion and Profit Shifting (BEPS) program, which is a massive program aimed at terminating certain loopholes that have resulted in opaque and aggressive income-shifting arrangements. As channels of paper shifting shrink, there has been increasing interest in real-shifting strategies. For example, De Simone and Olbert (2019) find that multinational firms increase their use of real-shifting strategies when the cost of paper shifting strategies increase. My study contributes to this growing literature by studying a multinational corporation's capital allocation decision in response to tax incentives, which is a real-shifting strategy, and how this strategy trades off its tax purposes against its managerial implications.

Existing literature on the intersection between tax and managerial considerations centers on the transfer-pricing decision in relation to income-shifting. Theoretical studies focus on the tradeoff between the tax and managerial implications of the internal transfer price. In the following subsections, I will discuss in detail the managerial considerations associated with a transfer-pricing decision, the tax implications of the transfer-pricing decision, and the interaction between these two considerations that the literature has considered so far. I will also discuss in detail the empirical studies that have established the existence, determinants, and consequences of income-shifting, together with the various estimation methods.

2.1.1 Transfer-pricing: Managerial importance

Starting in the middle of the twentieth century, there has been significant growth in both organizational size and organizational forms. As multi-divisional firms became increasingly popular, the literature started to examine factors that contribute to centralized versus decentralized management. A popular argument for decentralization often hinges on the information asymmetry between the headquarters and the subdivisions. More recent studies in management recognize many other benefits of decentralization to achieve differentiation strategies for multinational companies. As discussed in Cook (1955), the transfer price between divisions plays a key role in ensuring that the right incentive is given. He discusses several transfer-pricing approaches and analyzes the pros and cons for each.

Hirshleifer (1956) models a manufacturing subdivision that supplies products to the downstream parent purchaser. The approach that parent adopts to achieve the most efficient outcome depends on whether the manufacturing division can sell to an external market. He shows that if the external market exhibits perfect competition, then transferring at the market price is the most efficient. Hirshleifer (1957) models a situation where the revenue and cost of two divisions are indirectly related through production quantity, so demand changes in one division also cause changes in the marginal cost to the other. As a result, if each division maximizes its own profit, it is not optimal for the entire group because the changes in the marginal cost in the other division are not considered. He then shows that if the transfer price reflects the changes in the other division, it helps each division to internalize the overall organizational profit. An important assumption in the above studies is that the parent has sufficient control to obtain the cost information from the subdivisions. As this feature is unlikely to hold in a decentralized organization, more recent studies have started to incorporate information asymmetry into their models.

Baldenius and Reichelstein (2006) model one central office and two subdivisions, one downstream and one upstream, each facing its own external market. In this structure, there are two types of information asymmetry: one exists between the central office and the divisions, and the other exists between the two divisions. More specifically, the manufacturing division can observe the realized condition of its own market and the purchasing division's market, but the purchasing division can observe only the realization of its own market, while the central office can observe neither. The authors establish a relationship between the internal transfer price and the subdivision's ability to respond to its external market. They find that transferring at the market price is not always efficient; instead, transferring at a discount is better when the manufacturing division has monopoly power in its external market. This is because when the manufacturing division faces the same price internally and externally, its internal supply subsidizes its production, so it has the incentive to over-supply the internal market instead of fully taking advantage of its external market.

Other studies have examined the implication of internal price to the firm's external relationships. Arya and Mittendorf (2007), for instance, show that one benefit of having a decentralized organization is to reduce the cost paid to external suppliers. In their model, the upstream division supplies one type of input to the downstream division that also needs to source another type of input from an external supplier. The downstream division then sells its final product in a competitive market following a Cournot market. The external supplier can observe the transfer price charged internally to the downstream division for the first type of input. A higher internal price reduces the total residual profit available for the downstream division, so even with the same negotiation power, the external supplier gets a smaller share of the total profit available, allowing the firm to retain more profit within the organization. The authors highlight the point that even though decentralization does not directly improve the downstream division's competitive position, it benefits the organization by improving the negotiation outcome with its external suppliers.

Two studies examine the effect of a firm's internal transfer price on its relationship with its external competitor in the context of forming collusions. Narayanan and Smith (2000) model a manufacturing parent and a purchasing subsidiary that sells a product to its own external market that can be either a monopoly or a Bertrand duopoly. They show that observing a higher internal transfer price charged to the purchasing subsidiary deters the other player in the duopoly from engaging in a price war. They suggest forming collusions instead of maintaining rivalry as a benefit of decentralization.

Examining the same question but with different underlying assumptions, Chen and Shor (2009) show that under a Cournot market, collusions formed by firms through decentralization increase the profit for everyone in the collusion, but centralization remains the Nash Equilibrium without co-operation. Similar to the study of Narayanan and Smith (2000), in Chen and Shor (2009), decentralization allows the supplying division to charge an artificially high price so that the purchasing division must sell at a higher price in its final product market. If every firm decentralizes, then the market price will increase through a collusion of choosing decentralization. However, decentralization would no longer be a firm's best response if there existed another firm that does not choose decentralization.

A critical assumption in the study of Narayanan and Smith (2000) is that the other player can observe the internal transfer price and the firm can credibly communicate its transfer price. The internal transfer price acts as a lower bound to the price that the purchasing subsidiary can charge in its external market, so that the other player has no incentive to set the price lower than the cost that the purchasing subsidiary has paid internally. There are challenges to an organization's implementation of this assumption. One such challenge is that making the internal transfer price observable to competitors can encourage predatory behavior to the upstream division if the transfer price is too low. For example, Bolton and Scharfstein (1990) model predatory behavior in a two-period game where the headquarters' allocation of resources to its subsidiary depends on the first-period performance. They find that a competitor can successfully attack if its rival's performance in the first period is so bad that it receives no additional resources from its own headquarters in the second period.

Another challenge is that the internal transfer price must not only be observable but also be sufficiently credible to the competitor. If the competitor senses that a different transfer price exists internally or that the purchasing subsidiary will be compensated in some other way, then this effect will disappear. Chen and Shor (2009) posit that the assumption of a Cournot market alleviates the concern about a credible commitment of the internal price, while Narayanan and Smith (2000) suggest a tax cost as a possible signal for the firm to credibly commit to such internal prices. For example, if a competitor observes a high transfer price between a purchasing division that is in a high-tax jurisdiction and a supplying division that is in a low-tax jurisdiction, then this high internal transfer price is more credible for tax reasons. On the other hand, the internal transfer price is less credible if the purchasing division is in a low-tax jurisdiction. However, this approach presents two limitations. First, its use is limited if the competitor has reason to suspect that the firm may use a different managerial transfer price from its tax transfer price. Second, it remains an outstanding question as to whether and how a firm could release its tax transfer prices to parties other than the tax authorities.

2.1.2 Transfer-pricing: Tax importance

Halperin and Srinidhi (1987) model a transfer price as a determinant for production decisions and study how transfer price regulations for tax purposes distort production decisions. However, their model assumes a centralized organization. This is consistent with the relationship that governs the domestic parent and its foreign subsidiaries in the earlier stage of international business. In a follow-up paper, Halperin and Srinidhi (1991) consider a foreign supplying division that supplies an intermediate good to a domestic purchasing division. The transfer price between the two divisions is the same for incentive and tax purposes. They then consider three transfer-pricing methods and discuss the production quantity associated with each method. They show that without external constraints posed on the transfer price, the quantity produced would be optimal.

Baldenius, Melumad, and Reichelstein (2004) consider the tax implications together with the managerial incentive that an internal transfer price provides. They model a decentralized organization where a foreign subsidiary supplies one type of product to a domestic subsidiary, and the foreign tax rate is lower than the domestic. They show that the transfer price that results in maximum tax savings can differ from the transfer price that incentivizes optimal production quantity. The intuition for this result follows that from Baldenius and Reichelstein (2006). Charging a high transfer price to the high-tax parent achieves more tax savings, but this high transfer price results in a marginal revenue so high that the foreign subsidiary loses its incentive to take full advantage of its external market. Instead, it over-relies on its sales to the internal market. They obtain an additional insight that differs from Hirshleifer (1956) by showing that the incentive transfer price must exceed the cost to the supplying division to account for the tax considerations.

Hyde and Choe (2005) study a similar context but focus on the interaction between the transfer price for accounting and for tax purposes. They model a domestic parent supplier and foreign purchasing subsidiary, but the domestic tax rate is lower than the foreign tax rate. The parent sells to both its external domestic market and its foreign subsidiary. The foreign subsidiary then sells to its market and maximizes its own accounting income after tax. They consider a sequential game where the parent moves first and decides on both the accounting and the tax transfer price. The parent also decides on the quantity that it sells to its own domestic market. The foreign subsidiary then decides on the quantity to purchase from the parent, the same quantity that it then sells in the foreign market. They first find that the tax-efficient transfer price would be too high to incentivize the foreign subsidiarity to purchase enough quantity to sell in the foreign market. This is a finding consistent with that of Baldenius, Melumad, and Reichelstein (2004). However, they then show that external shocks to the tax transfer price, such as regulation changes, change the accounting transfer price that is internal to the firm. Similarly, internal factors, such as increases in cost, that change the internal price also change the transfer price for external tax purposes. Essentially, if one price changes and results in an undesirable quantity change, the firm can mitigate this problem by adjusting the other price.

Smith (2002b) considers a parent principal and a foreign subsidiary agent that decides on two sets of effort, one devoted to the product supplied to the parent, and the other devoted to its own market. The two sets of efforts are independent, and the two types of products are also independent in terms of their profitability. Smith (2002b) further incorporates a compensation scheme to the agent that is a joint function of the transfer price and the agent’s profit in its own market. He separately considers the two cases where the transfer price for compensation purposes is the same as, or differs from, the transfer price for tax purposes. He finds that when they are the same, there is a tradeoff between the tax benefits and providing incentive for the agent.

The tax motivation for setting internal transfer prices can affect a firm's investment. Smith (2002a) models a centralized organization that makes a domestic and foreign investment. He first establishes the benchmark case when the transfer price for tax purposes is not tied to the investment level. In this case, the firm can optimize its investments without any concern for the tax consequences, consistent with Halperin and Srinidhi (1991). Smith (2002a) then considers the implication for a firm's investment when the transfer acceptable to the tax authorities must be tied to the investment level. He shows that these transfer-pricing regulations distort investments as compared to the benchmark case. He further shows that the level of discretion allowed under each transfer-pricing method can either mitigate or exacerbate these distortions.

Sansing (1999) compares the level of investment made between two independent parties and that made between two parties in a parent-subsidiary relationship. The independent relationship suffers from a hold-up problem, while the parent-subsidiary relationship suffers from an incentive alignment problem. He shows that because the level of investment differs between these two cases, the resulting transfer prices must also differ. This result presents challenge to the application of the "arm's length" transfer price rule that tax authorities often require. Because the relationships are fundamentally different, the investment decisions that drive the transfer prices under the two systems cannot derive from comparable circumstances.

Martini, Niemann, and Simons (2012) model a parent and two subsidiaries that face different tax rates. One subsidiary supplies an intermediate good to the other which then sells to its own external market. They further assume that the supplying subsidiary cannot sell to its external market. In addition, the two subsidiaries make simultaneous investments that are either value-enhancing or cost-reducing. The key issue in their study is whether the investments made by the two subsidiaries are optimal. They use the level of optimal investments derived when the headquarters dictates all decisions as a benchmark and compare it with decentralized decision-making. They show that exogenous transfer-pricing rules required by the tax authorities can induce different levels of investment. These results closely resemble the hold-up problem and are contingent on several assumptions. First, no information asymmetry exists between the headquarters and the subsidiaries regarding the functional form of the investment decision and the realization of the investments. Second, the headquarters can decide and enforce the quantity produced. Finally, the transfer price is not a decision variable that the headquarters could use to incentivize investment decisions.

In summary, an MNC's transfer-pricing decision has important tax implications and serves various managerial roles such as incentivizing different production units to produce the optimal quantity, to internalize the incentive of the overall organization in its investment decisions, and to incentivize an optimal level of effort. However, these setups are most appropriate when physical goods are transacted and when there is a well-defined vertical supply chain. In addition, the literature has not considered other important decisions that multinational corporations make that bear both a tax and managerial consequence. My study contributes to this literature by considering a setup where the subsidiary relationship is characterized by the collaboration and flow of intangible knowledge rather than of physical goods. As discussed in Section 2.2, modern international business models emphasize the lateral relationships that subsidiaries form with one another, especially when knowledge integration forms a business's core competence. In this context, my study addresses the central allocation of capital resource, which is a decision that bears both a tax and a managerial consequence but has not been explored in the literature.

2.1.3 Income-shifting: Theoretical basis and empirical findings

In general, two types of system exist concerning taxing the profit earned by the foreign subsidiaries of a multinational corporation. The worldwide system taxes such income as earned domestically but applies a foreign tax credit against the domestic taxes otherwise payable, while the territorial system exempts such foreign income from domestic taxation. With the territorial system, an income-shifting strategy achieves permanent tax savings, while with a worldwide system, income-shifting technically achieves only tax deferrals, until such time that the income is repatriated back home. This raises the question about how much benefit firms derive from the income-shifting that achieves only temporary tax deferrals. Prior to the Tax Cut and Jobs Acts (TCJA) reform of 2017, the U.S. had its worldwide system for a long time, yet a number of studies have documented that U.S. multinational companies engage in income-shifting behaviors (Dyreng and Markle 2016, Klassen and Laplante 2012b, Markle 2016). There is a long line of inquiry into the cost and benefits of income-shifting, even when the benefits seem only temporary.

Under the worldwide system, a firm can either repatriate its foreign earnings and incur immediate taxes, or reinvest abroad and continue deferring taxes. Hartman (1985) and Sinn (1993) first modeled this decision. Hartman (1985) distinguishes mature from immature foreign operations and finds that a firm with a mature foreign operation is indifferent between reinvestment and repatriation when the after-tax foreign return equals the after-tax domestic return. More importantly, this decision is independent of domestic tax policies. Sinn (1993) incorporates the growth and maturity of a firm by considering a two-period model where the corporation decides on the value of an initial investment in the first period and the value of reinvestment or repatriation in the second period.

Weichenrieder (1996) extends the Hartman-Sinn model by allowing foreign reinvestments to be in financial assets. Altshuler and Grubert (2002) further extend the model to include strategies that use passive investments to achieve the economic equivalence of repatriation without incurring repatriation taxes. Klassen, Laplante, and Carnaghan (2014) extend Altshuler and Grubert (2002) to include the possibility of income-shifting and find that if the foreign required rate of return is low, then shifting occurs and reinvestment is better than repatriation; but when the required return is high, no shifting occurs and repatriation is better than reinvestment.

Although earlier studies do not document income-shifting behaviors by U.S. multinational corporations (Collins, Kemsley, and Lang 1998), more recent studies provide corroborating empirical evidence of such behavior. Clausing (1998) and Clausing (2003) find that prices of intra-organizational transactions of U.S. multinational companies vary with tax incentives, namely the tax differential between the transacting parties. Clausing (2009) shows that the U.S. loses 35% of its 2004 corporate tax revenue due to income-shifting. Klassen and Laplante (2012b) find that U.S. firms have become more aggressive income-shifters over time. Dharmapala and Riedel (2013) find evidence of profit shifting in the European Union. Using data from the Internal Revenue Service (IRS), De Simone, Mills, and Stomberg (2019) provide empirical evidence that U.S. multinational companies shift income through inter-company payments to low-tax subsidiaries. Markle, Mills, and Williams (2019) suggest that the real extent of shifting could even be higher than what is revealed in these measures, after accounting for any potential implicit taxes.

In addition to establishing empirical evidence for the existence of income-shifting, the literature also examines its determinants and consequences. Studies find that firms shift more income when they face better foreign reinvestment opportunities or have higher financial reporting incentives (Klassen and Laplante 2012a), when they have less financial constraints (Dyreng and Markle 2016), and when they are subject to a territorial tax system that does not impose domestic taxes on foreign income (Markle 2016). Studying an exogenous shock to firms' financial reporting regulations, the implementation of the International Financial Reporting Standards (IFRS), De Simone (2016) finds that IFRS adopters engage in a more aggressive income-shifting strategy than non-adopters after mandatory IFRS adoption. Using affiliate-level data, De Simone, Klassen, and Seidman (2017) document that while firms respond to tax incentives to shift income to low-tax subsidiaries when the subsidiaries are profitable, the opposite is true when the subsidiaries have losses. In other words, firms also respond to tax incentives to shift to high-tax subsidiaries that have losses. On the consequence side, De Simone, Klassen, and Seidman (2019) develop a firm-specific income-shifting measure and find that firms that engage in more tax-motivated incomes shifting respond to investment opportunities less efficiently than those that engage in less income-shifting.

The above studies use direct empirical proxies that generally fall under two categories. The first method follows Hines and Rice (1994) who model pre-shifted income as a Cobb-Douglas production function of inputs, and the degree to which the difference between the observed income and the output from the Cobb-Douglas function is correlated with jurisdictional tax rates is considered shifted income for tax reasons. Huizinga and Laeven (2008) enhance the model by including an affiliate-level tax incentive variable to better capture tax-motivated income-shifting. With this method, any profit that is above the level predicted with economic factors and responds to tax incentives is considered tax-motivated income-shifting.

The second approach builds on Collins, Kemsley, and Lang (1998) who assume that a firm has the same profitability across all countries, absent income-shifting. They then define shifted income to be the correlation of the difference between foreign and total profitability that can be explained by tax incentives. Collins, Kemsley, and Lang (1998) measure profitability by the return on sales and tax incentives by the difference between domestic and foreign tax rates (FTR). Klassen and Laplante (2012b) improve the Collins, Kemsley, and Lang (1998) model by using an instrumental variable and changing the annual FTR to a 5-year FTR measure. It is worth pointing out that the first method considers location-specific factors that may affect an affiliate's profitability, but both methods treat the profitability across subsidiaries as independent of one another.

Dyreng and Markle (2016) take a different approach by requiring the profits shifted to equal the profits shifted out. They propose estimating two simultaneous equations that the two directions must satisfy. Their method is based on the premise that reported pre-tax income is after shifting but reported sales are not. Their reason is that whereas the recognition of pre-tax income is based on the legal domicile of the income-earning entity, the recognition of sales is based on the location of third-party customers. Furthermore, income-shifting transactions change the legal entitlement of income among entities but not the location of external customers, so they only affect income but not sales.

In addition to these direct measures of income-shifting, studies have also documented evidence of income-shifting with indirect measures. Desai, Foley, and Hines (2006) show that firms shift income to tax havens to defer U.S. taxes. Dyreng and Lindsey (2009) find that U.S.

firms who disclose their presence in tax havens bear less overall tax burdens than firms who do not disclose their presence in tax havens. Using indirect measures, the literature documents several consequences. When shifted income is subject to a future repatriation tax, companies tend to have an excessive cash holding offshore (Foley et al. 2007), and a high amount of trapped cash can translate into a low return on the foreign investments (Edwards, Kravet, and Wilson 2016). Akamah, Hope, and Thomas (2016) find that firms with a heavier use of tax havens report geographic earnings at a more aggregate level. Williams (2018) find that U.S. jobs are more likely to be lost to countries with lower tax rates, suggesting that firms move not only income but also jobs to tax-favored jurisdictions.

In summary, the empirical literature provides strong evidence that multinational corporations engage in income-shifting strategies. Determinants of such behaviors include a firm's financial constraints, financial reporting regulations and incentives, opportunities in the foreign markets, and the tax status of a foreign affiliate. Firms that adopt income-shifting strategies likely have a presence in tax havens and create an opaque reporting environment. The empirical literature generally regards the multinational firm as an internally coherent decision-maker and has not addressed the various players with different incentives that contribute to the observed behaviors. My study contributes to this literature by incorporating the coordination cost associated with managing the different internal parties and by studying how this coordination cost affects a firm's response to tax incentives.

2.1.4 Tax implications of intellectual properties (IP)

With technology taking a more prominent place in international business strategies, the tax literature has also examined the tax incentives in relation to the development of IPs. The development and ownership of intellectual properties is another important tool to achieve income-shifting. By wholly or partially owning an IP, a low-tax subsidiary can receive large amounts of future royalty payments to be taxed at its low tax rate. Several studies document that tax incentives for R&D are associated with higher IP ownership (Böhm et al. 2015, Bradley, Dauchy, and Robinson 2015, Ernst and Spengel 2011, Griffith, Miller, and O'Connell 2010, 2014, Karkinsky and Riedel 2012). My study contributes to this literature by establishing that the development process itself can also affect a multinational corporation's response to surrounding tax incentives.

Magelssen (2020) studies the effect of owning IP on a subsidiary's innovative ability and quality. From a business strategy perspective, she theorizes that ownership of IP conveys income and decision rights to the subsidiary, so the subsidiary has greater autonomy to innovate. She finds that while ownership of IPs is positively associated with tax incentives, subsidiaries that are IP owners respond more efficiently to increases in local R&D opportunities than those that are not IP owners, suggesting that ownership of IP, even for tax reasons, improves the efficiency of local innovations. De Simone, Huang, and Krull (2019) show that while tax incentives explain paper income-shifting behaviors by multinational corporations that exploit domestic developed R&D, wage incentives are responsible for explaining real income-shifting behaviors of multinational firms that exploit foreign-developed R&D. Although both tax and wage benefits lead to the observation of higher foreign preferabilities, they find that the factor with the greatest benefits to be mainly responsible for explaining this phenomenon. Huang, Krull, and Ziedonis (2019) document that tax incentives provide additional benefits for multinational firms to include cross-border partners in developing patents.

De Simone and Sansing (2019) model a situation where a U.S. parent company owns pre-existing IP to be further developed with a foreign subsidiary. The U.S. parent decides on the method for joint development, and the subsidiary does not provide any input into this decision.

They discuss situations under which the parent company would use a cost-sharing arrangement. Under a cost-sharing arrangement, the MNC could take advantage of the information asymmetry on the expected value of the IP to the tax authority. However, the tax authority might pursue an audit that challenges the MNC's assessment. They show that the MNC prefers the cost-sharing arrangement when its incremental benefit is high, when the tax authority's information asymmetry is high, and when the cost of enforcement is high.

Reineke and Weiskirchner-Merten (2020) consider a domestic headquarters and two subdivisions, where the domestic division faces a higher tax rate than the foreign division. The headquarters has existing IP that the two subsidiaries can use without any further development. The headquarters decides on the ownership of this IP and the royalty rate that the owning party charges. They omit the price at which ownership transfers from the headquarters to the subsidiaries. After the headquarters' decision, each subsidiary then takes action regarding the use of this IP. One subsidiary's use generates a benefit to the other subsidiary that does not depend on the other subsidiary's action. Furthermore, this externality is purely coincidental and not controlled by any action of the subsidiary, so the two subsidiaries are independent of each other in this sense. They show that the tax benefits derived from the ownership and royalty payment decisions are subject to the non-owning subsidiary's under-investment of effort, which, in turn, affects its coincidental externality conferred to the other subsidiary. A critical assumption in Reineke and Weiskirchner-Merten (2020) is that the return from one's own effort does not depend on the effort of the other. There is no joint project which the two subsidiaries develop together and there is no issue of sharing any profits from a joint development, unlike the relationship-specific investment considered in the case of the hold-up problem.

Whereas most studies focus on the effect of tax incentives on the use of IP, my study focuses on the development of IP and specifically considers the active contribution of each subsidiary in the innovation process. As discussed in Section 2.4, cross-functional collaborations are critical to the success of an innovation. I incorporate this key element of the development process by studying a situation where without one subsidiary's active contribution, the other subsidiary cannot pursue the innovative opportunity alone. Furthermore, my study extends this literature by offering a prediction on the responsiveness of capital allocation to tax incentives, which is a decision that has not been addressed in this literature. Finally, the differential responsiveness depends on the coordination needs within an MNC.

2.2 International Business Literature

The development in the international business literature has strongly influenced the setup in my study. In this section, I will discuss in detail how this literature has evolved in its view of the multinational entity and the theory's implications for the parent-subsidiary relationship and the relationships that subsidiaries form with one another. The parent-subsidiary relationship has evolved as subsidiaries develop new mandates and accumulate new expertise and resources. Several review papers, such as Westney and Zaheer (2009) and Tallman and Yip (2009), discuss the challenges and opportunities that the complexity of the multinational environment presents to the parent-subsidiary relationship, and how they differ from those present in purely domestic firms (Paterson and Brock 2002, Tallman and Yip 2009, Westney and Zaheer 2009). They synthesize both external and internal factors that the literature has documented to influence the parent-subsidiary relationship.

2.2.1 Factors that determine the parent-subsidiary relationship

Roth and O'Donnell (1996) adopt a principal-agent framework to study factors that contribute to an agency issue at the subsidiary level. The authors use the extent of an incentive-based compensation to proxy for the severity of the agency issue at the subsidiary level. Surveying more than 100 firms, the authors propose and test several of its main determinants. First, the difference between the culture in the country of the headquarters and the culture in the country of the subsidiary creates obstacles for the headquarters to learn about the local condition of the subsidiary, thus increasing information asymmetry between the two parties. Second, managerial discretion is often given to subsidiaries that share interdependent processes to allow for effective and timely decision-making. These subsidiaries are often part of a complex supply chain where it is difficult to separate one party's input from another in the output. This means that direct monitoring is not possible because each subsidiary's action cannot be traced directly to an outcome. Furthermore, a subsidiary has a greater decision power if it possesses specialized knowledge that is critical to a value-adding activity, especially in firms that are heavy on research and development. Finally, the organizational culture can influence the degree that the subsidiary identifies with and commits to the parent company, and organizational identity and commitment motivate the subsidiary to adopt more of the overall organizational goal.

Ghoshal and Nohria (1989, 1994) find that the parent-subsidiary relationship is not simply an organizational construct but varies greatly across subsidiaries within the same organization. They document that when the local environment that a subsidiary operates in is complex, local knowledge becomes relatively more important, and the subsidiary has greater influence in decision-making. They also find that subsidiaries that are endowed with more resources are less likely to submit to the central management. Resource-independent subsidiaries are often also independent on other fronts. Furthermore, being the holder of valuable assets, tangible or intangible, makes the subsidiary important not only to the MNC but also to the local economy, and thus confers power to the subsidiary in the decision-making process. Finally, the authors find that in managing a subsidiary that has power, coordination is a more desirable managerial approach than giving direct orders.

Ghoshal and Bartlett (1990) introduce a novel management theory that uses network theory to explain the difference in the parent-subsidiary relationships within a multinational entity. They characterize the parent-subsidiary relationship based on two resource allocation patterns. The first characteristic is whether resources are concentrated in one location or are scattered all over the organization, which the authors term "dispersal." With a dispersed allocation, the organization often has repeated functions and expertise at different locations. The second characteristic is whether one location's function can supply the worldwide need of the organization in that one area, which the authors term "specialization." The researchers then study the effect of a subsidiary's role within its external network on the relationship it has with the parent. If a subsidiary operates in an environment where key external stakeholders form a tight relationship, then success in that local market requires the subsidiary to be a member of the close circle that connects with all the external stakeholders. In this case of a high "within density," the subsidiary is equipped with multiple functions, and the organization adopts a high-dispersal and low-specialization strategy. However, this challenge can be overcome if the expertise can be easily accessed from another location, which the authors term an "across density" of the external network. In this case, the organization is free to specialize and optimally locates special resources at important hubs that serve multiple locations.

Ghoshal and Bartlett (1990) further consider how a subsidiary's network properties influence its bargaining power and decision-making autonomy. In an environment where the subsidiary forms a closed interaction with key external stakeholders (high within density), it becomes indispensable for the organization to access its market. The external barrier of entry then becomes the subsidiary's own protection and power to seek resources and independence. To explain the effect of the across density, the authors model the multinational entity as a network where each unit (including the parent) represents a node, and an edge exists between two nodes if the two units interact with one another. To effectively serve external stakeholders, some subsidiaries build connections with many other subsidiaries and become critical hubs that are indispensable for the organization to connect internal resources and expertise. The importance of these hubs allows them to possess many resources and become more independent from the parent.

O'Donnell (2000) compares the two theories in terms of their ability to explain the parent-subsidiary relationship. Under the first theory, that the author terms "agency theory," the headquarters uses a more direct monitoring when the subsidiary's local advantage is low and incentive schemes when the subsidiary's local advantage is high. The author theorizes that a subsidiary's local advantage and its specialized skillsets create more information asymmetry between the headquarters and the subsidiary, making monitoring more difficult and delegation more appropriate. Under the second theory, that the author terms "interdependence theory," the parent-subsidiary relationship depends on whether the subsidiary has a stronger reliance on the headquarters or on other subsidiaries. The author theorizes that the headquarters uses a vertical and formal control when the subsidiary's reliance is more toward the headquarters, and it uses horizontal and social methods when the subsidiary's reliance is more toward other subsidiaries. Collecting questionnaires from 255 parent-subsidiary pairs, the author finds that interdependence theory explains the variation in the parent-subsidiary relationships better than agency theory.

2.2.2 Active role of subsidiaries: Initiatives

The above studies show that a subsidiary's role within an organization can be assigned according to the organizational strategy. On the other hand, there are other studies which also show that subsidiaries can be active in forming the organization's competitive advantage and shaping its strategy (Burgelman 1983, Prahald 1976, Meyer, Tsui, and Hinings 1993, Birkinshaw 1997, Birkinshaw, Morrison, and Hulland 1995, Birkinshaw and Morrison 1995). Furthermore, there are studies which show that subsidiaries can act as entrepreneurs that actively identify opportunities that fit with their own value proposition and act upon these opportunities (Cantwell and Mudambi 2005, Delany 2000, Rugman and Verbeke 2001). The result of such initiatives strengthens the multinational organization's overall competitive position. The initiative in turn could help the subsidiary to gain more influence in the key decision-making processes (Ambos, Andersson, and Birkinshaw 2010).

Meyer, Tsui, and Hinings (1993) consider the advancement of organizational mandates as an iterative process between top-down and bottom-up reforms. In a more recent paper, Cuervo-Cazurra, Mudambi, and Pedersen (2019) combine the two perspectives to explain the evolution in the parent-subsidiary relationship. They posit that both the relinquishment of control from headquarters and the accumulation of power through resources have contributed to the increased scope in subsidiary roles and responsibilities.

Birkinshaw and Morrison (1995) discuss how the literature has evolved in its view of the organizational structure of multinational entities. They discuss that earlier theory regarded the multinational as a hierarchy where there is a well-defined vertical flow of responsibility, with formalized and tight control from the top (Williamson 1985, Chandler 1962). However, with more studies dedicated to subsidiary activities, subsequent researchers have found that subsidiaries can acquire mandates and develop expertise on their own. Furthermore, subsidiaries often interact with one another and form lateral relationships, and there are studies which propose a horizontal framework that addresses the interdependence among subsidiaries of the multinational's complex internal supply chain (Porter 1985, Prahalad 1987, Prahald 1976). As discussed in Porter (1989), this interdependence means that the return from one subsidiary's investment may be jointly determined by its own investment and the investment or action of another subsidiary.

Birkinshaw (1997) describes four types of initiative that a subsidiary may undertake and examines characteristics that are associated with each type. The first type is when the initiative mainly enhances the subsidiary's ability to serve the local market. With this type of initiative, no major hurdle exists for the headquarters to entrust the subsidiary with local responsibilities. The second type is when the initiative reduces the cost of a certain process or function that serves the entire organization. With this type of initiative, the subsidiary must possess a reputation or demonstrate to the headquarters its competitive advantage over other subsidiaries in the specific area. The third type is when the initiative allows the company to unlock new markets globally. With this type of initiative, the subsidiary is often recognized as the expert in the relevant area and has high autonomy and low interference from the headquarters. The final type is a combination between the second and third types, where the headquarters identifies such global opportunities and allows for a bidding process among subsidiaries. Among the 39 companies interviewed, more than a third of the companies have subsidiaries that contribute at the global level. This finding brings an important perspective that the intellectual capabilities held at the subsidiaries can collectively form a multinational organization's value proposition.

Several other related studies provide empirical evidence that supports the active role of subsidiaries. Cantwell and Mudambi (2005), for instance, find that subsidiaries that possess expertise engage in research and development that enhance the overall competence of the organization. Birkinshaw, Hood, and Jonsson (1998) survey 229 foreign subsidiaries of large multinational manufacturing companies and find that initiatives taken by subsidiaries can result in the development of new competencies that grant the organization access to a new market worldwide. Rugman and Verbeke (2001) confirm this finding and further study the process through which expertise developed in one subsidiary for one purpose allows the subsidiary to contribute to subsequent projects across location boundaries. Birkinshaw, Hood, and Jonsson (1998) find that subsidiaries with special resources are more likely to contribute to and lead the overall organizational strategy. They further find that subsidiary-level culture, not just the overall organizational culture, matters regarding whether a subsidiary takes such initiatives. Birkinshaw and Morrison (1995), collecting questionnaires from 126 subsidiaries of multinational corporations, find that subsidiaries that contribute outside of their own local market can make decisions that concern both their operations and their strategies.

2.2.3 Coordination as the most important function for headquarters

The parent-subsidiary relationship is important not only to the headquarters but also to the good functioning of subsidiaries. Taking the perspective of the subsidiary, Lunnan et al. (2019) survey 104 subsidiary managers and find that subsidiaries expect the headquarters to coordinate well and provide the necessary support to carry out their functions. Insufficient information, either due to purposeful withholding or ignorance in communication, hinders and delays decision-making for subsidiaries. They further discuss that renegotiations and changes of previously agreed upon arrangements also lead to waste and inefficient allocation of resources. This is a cost that the headquarters may not even recognize. The authors find that coordination mechanisms and empathy can improve the subsidiary's perception of the headquarters.

As subsidiaries become more dispersed and independent and receive less direction from headquarters, some researchers have begun revisiting the question of what is the essential value that the headquarters bring. As discussed in Ambos and Mahnke (2010) and Tallman and Koza

(2010), although subsidiaries can self-guide in their own responsibilities, they do not necessarily know the expertise available in other subsidiaries. In this case, the key advantage of the headquarters is its bird's-eye view that allows it to see the distribution of resources across all locations. A key function for the headquarters is to identify opportunities that combine the specialized resources from various locations and to arrange for subsidiaries to work together and share their resources. Another key function for the headquarters is to gather information globally and disseminate it to subsidiaries that cannot otherwise access the information, as suggested in Egelhoff (2010).

2.2.4 Knowledge management among multinational subsidiaries

Resource management among international subsidiaries is an important aspect that multinational entities must address to thrive in their complex environment (Barney 1991, Barney 2001, Peng 2001, Sirmon et al. 2011). Among the different types of resources, knowledge and its integration are at the core of the existence of multinational entities (Gupta and Govindarajan 2000, Porter 1986, Teece 1981, Zander and Kogut 1995, Spender and Grant 1996), and yet knowledge is the most difficult to manage. Knowledge exists in the forms of technical know-how, expertise, and experiences that are tacit and non-transactable (Dierickx and Cool 1989). This characteristic of knowledge creates significant barriers for its sharing and transfer, especially through formal processes (Teece 1977, Szulanski 1996, Subramaniam and Venkatraman 2001).

Bartlett and Ghoshal (1998) point out that many multinational companies have adopted a "differentiation strategy" (p. 44), where each subsidiary develops a unique niche according to its strength, and the niche is specific to the local market or serves a specific function within the organization. As a result, some subsidiaries become sole holders of critical intangible assets such as information, relationships, knowledge, and expertise. For initiatives that require these resources, the subsidiaries then are often the leader, instead of the headquarters. They find that a coordination strategy is more effective than direct control in mobilizing this type of resource, and that interactions and collaborations among subsidiaries can promote the sharing of these resources. Gupta and Govindarajan (1994) show that subsidiaries can innovate on their own and their innovation objectives in connection with other subsidiaries are consistent with their differentiated strategic roles within the multinational network, which is a concept discussed in Ghoshal and Bartlett (1990).

The implication of the above discussion is that knowledge is often scattered across subsidiaries, yet it is a collection and integration of all available knowledge and expertise which composes the multinational's core competence. The dispersion and non-transactability of knowledge make it especially important for the headquarters to facilitate and oversee the transfer and sharing among subsidiaries (Ambos and Mahnke 2010, Ciabuschi, Martín, and Ståhl 2010, Tran, Mahnke, and Ambos 2010).

In general, there are two types of knowledge, that which can be described and encoded easily, such as facts and procedural documentations, and that which is tacit in nature and cannot be transcribed easily. As discussed in Lippman and Rumelt (1982) and Zander and Kogut (1995), it is the latter type that allows companies to sustain competitive advantage because competitors may observe the final product but cannot reverse-engineer to recreate the product. However, it is also this latter type that creates difficulties for knowledge-sharing, even among parties internal to the organization. Tacit knowledge is important not only to the overall organization but also to the subsidiary that seeks an innovative opportunity (Sheng and Hartmann 2019). Szulanski (1996) and Gupta and Govindarajan (2000) find that barriers to effective learning among subsidiaries include the perceived value of the knowledge being shared, the recipient's attitude and ability toward learning, and the relationship between the origin and the receiving subsidiaries.

Hedlund (1994) finds that with tacit knowledge, collaborative horizontal management is more effective than formal vertical management. The objective is to combine knowledge through providing opportunities for subsidiaries to interact and work with one another. Subramaniam and Venkatraman (2001) find that the ability to connect the necessary and relevant skillsets across international subsidiaries is an important determinant of the multinational's ability to innovate for multiple markets. They further find that teaming up subsidiaries from different locations is an effective way of combining knowledge and facilitate organizational learning. Mahnke and Venzin (2003) confirm the value of such teams but find that the headquarters' oversight is important to ensure that these teams have the right incentive to collaborate toward the overall organizational goals.

Ciabuschi, Martín, and Ståhl (2010) report similar findings on the immense value that the headquarters brings through its function of coordinating knowledge-sharing. They discuss three tools that the headquarters can use to accomplish this task: allocating appropriate and adequate resources, delegating the appropriate types of decision rights, and minimizing direct monitoring in the process. Mahnke, Venzin, and Zahra (2007) discuss the headquarters' role in facilitating and consolidating the opportunity identification activities that are dispersed across subsidiaries. They argue that the unpredictable behavior and interests of the other parties involved could greatly hinder this process. As a result, the headquarters plays an important role in incentivizing the different parties to act in one accord. They find that in addition to designing the incentives, the headquarters' commitment to them also affects the incentives' effectiveness.

The need for coordination from the headquarters also arises to balance power between subsidiaries endowed with a higher amount of IP and those endowed with a lower amount. Ram and Pietro (2004) find that if the subsidiary develops a significant intangible property that is of value to the business, it gains bargaining power to share more in internal resources. This power plays out not only in the vertical relationship with the headquarters but also in the horizontal relationship with other subsidiaries. The authors combine survey data, patent data, and financial reports and find support that subsidiaries endowed with knowledge possess power to influence group decisions. They proxy the transfer of knowledge to the parent in the form of dividends and royalties paid to the parent.

Dellestrand and Kappen (2012) examine the headquarters' involvement from the perspective of subsidiary differences. They discuss the importance of headquarters' involvement in the transfer of innovation projects between subsidiaries. They examine 169 such transfers and find that the extent of human and organizational resources dedicated by headquarters to these transfers varies significantly across organizations. They posit that headquarters' involvement and mitigation are especially needed when the transferrer and transferee subsidiaries are not familiar with one another and face information asymmetry. Their main construct is the distance between the two subsidiaries in four dimensions: geography, culture, language, and local environment. They find that greater distance leads to a significantly higher amount of resource dedicated from the headquarters to the transfers.

2.2.5 Competition among subsidiaries

Stein (1997) models a situation where the headquarters has limited capital resources available for allocation. The implication is that the optimal amount allocated to one project is not only a function of its own profitability but also the profitability of other projects. When the headquarters adopts a winner-picking strategy in its capital allocation, subsidiaries access the same pool of capital and must compete. As a result, the capital allocated to one subsidiary has an opportunity cost that equals the profit that could be earned in another subsidiary. This opportunity cost is an important consideration for the headquarters' capital allocation decision in my study.

Procher and Engel (2018) examine an inter-temporal relationship between international divestment. They build on existing theory on competition among subsidiaries and argue that domestic and foreign subsidiaries do not compete on the same ground. They find that within the multinational network, domestic subsidiaries are more likely to compete with domestic and foreign subsidiaries with foreign. They provide empirical evidence for this competition by documenting that domestic divestment is strongly associated with current-period domestic investment and vice versa, whereas the respective foreign investment/divestment does not matter. Similarly, prior-period foreign investment is shown to be strongly associated with current-period foreign divestment and vice versa, whereas the respective domestic investment/divestment does not matter. Birkinshaw and Lingblad (2005) conceptualize the competition among subsidiaries as the extent of similarities between their tasks or the ways through which they add value. They theorize that subsidiaries that face blurred definitions of boundaries are more likely to face competition, because they are also more likely to share similarities. They find that this occurs when subsidiaries face ambiguous external opportunities and operate in less mature markets.

In summary, a major development in the international business literature is the shift from treating the multinational group as a vertical hierarchy to treating it as an interrelated network. This development reflects differentiation among subsidiaries that lead to the development of subsidiary-specific resources in the form of knowledge, expertise, and connections to local and global partners. The literature further documents that subsidiary initiative and autonomy often lead to subsidiaries gaining their own niche and becoming the owner of their subsidiary-specific resources. The access and integration of these subsidiary-specific resources are important to the creation of new organizational competencies. As a result, the headquarters plays a crucial role in coordinating the different subsidiaries to contribute their respective expertise. Taken together, the multinational corporation has a unique opportunity to innovate with subsidiary collaborations but also faces a unique challenge to coordinate cross-subsidiary activities. This unique opportunity and challenge are at the heart of this thesis. My study concerns a setting where each subsidiary has its own subsidiary-specific expertise, and a unique innovative opportunity exists but requires expertise from both subsidiaries. The headquarters plays a crucial role in the coordination of the two subsidiaries' actions, because each subsidiary is the owner and has full control rights over its own subsidiary-specific knowledge.

2.3 Joint Investment

In this section, I review the literature concerning joint investment made by two parties. This literature ties closely with my thesis, because the setup that I examine in this thesis includes two parties that interpedently make an investment decision in addition to their respective intellectual contribution decision. As discussed at the end of this section, whereas most studies in this literature concern the amount of investment a party makes without an opportunity cost, my study addresses the type of investment a party makes with an opportunity cost that equals the profits otherwise earned on the other project.

2.3.1 International joint venture

In this thesis, I examine the coordination issue among international parties in the context of a multinational corporation, but the coordination issue is also present in other forms of conducting international businesses such as international joint ventures. Desai, Foley, and Hines (2002) and Desai, Foley, and Hines (2004) find that U.S. firms became less likely to use IJVs over the fifteen-year period up until their studies. They attribute the decline to the increasing coordination cost associated with IJVs caused by three main factors. First, the international joint venture (JV) partner may have different business objectives than the local JV partner. Second, the international JV partner may be concerned with the appropriation of intellectual property by the local JV partner. Finally, the transfer price that is optimal for incentive or tax reasons for the international JV partner may not be optimal for the local JV partner.

A key advantage of international collaboration is to access new expertise relevant to the local market held by the foreign party. Desai, Foley, and Hines (2002) find that IJVs are desirable when most of the activities conducted by the foreign affiliate are with foreign (local) parties. Desai, Foley, and Hines (2004) examine the relationship between tax-planning and the cost to coordinate with an external JV partner by comparing reported profitability at the affiliate level of wholly owned versus partially owned affiliates. They find an overall negative association between reported profitability and the affiliates' tax rate but find a less negative association for partially owned firms. The authors find that royalties payments to the parent are significantly higher for wholly owned affiliates than partially owned affiliates. The authors interpret the result as having more transfers of IP with wholly owned than with partially owned affiliates. While the result is interesting, there is some concern regarding its interpretation. While the evidence could suggest a higher use of IP by wholly owned affiliates than partially owned ones, one must not confuse the use of IP with its transfer. Recent studies show that whether to transfer an ownership of IP to local subsidiaries (especially those located in low-tax jurisdictions) is an important consideration in an MNC’s tax plan (De Simone, Huang, and Krull 2019, Schwab and Todtenhaupt 2019). Furthermore, Desai, Foley, and Hines (2004) find that affiliates located in countries that have a higher tax-rate differences are associated with a higher likelihood of being wholly owned than partially owned. They posit that wholly owned affiliates can better facilitate tax-planning.[2]

Reviewing the literature, Desai, Foley, and Hines (2004) point out the moral hazard problems JVs face and the scenarios where they are efficient. Cramton, Gibbons, and Klemperer (1987) model a situation where each partner has a private intrinsic value toward a shared asset. The authors propose a bidding process that efficiently allocates value to each partner. Hart and Moore (1998) model the choice of two ownership structures, one with an outsider owner and the other owned by members of the group (such as a cooperative). They find that the cooperative performs better only if each member has the same outside option and values the product in the same way.

The IJV being considered by these authors are between a U.S. firm and a local partner. There are situations where the IJV is between two international partners located in different countries and a local party. The tax objectives of the two international partners may differ and lead to different preferences over where to retain after-tax earnings and where to locate the developed intellectual property. The incentive and coordination issues when there are three parties involved in the IJVs have not been addressed in these papers.

Aghion and Tirole (1994) model a research division with a sole purpose of developing an intellectual property and a financing party who benefits from the intellectual property. A key feature in their model is that the innovative outcome cannot be specified ex-ante. The exact features of the product are unknown, even to the innovation team, before the product is built. I make the same assumption in my model based on the ill-defined nature of an innovative endeavor. However, the issue that Aghion and Tirole (1994) consider is the ownership right that

[2] These papers do not consider situations where the ownership of the foreign affiliate is not even high enough to qualify for the foreign affiliate definition (for example, less than 10% as in Canadian tax law), where the income is treated as investment income, and there is no tax deferral.

entitles all residual use of the property, motivated by the incomplete contract on the use of the intellectual property, in the sense of Hart and Moore (1988). In Aghion and Tirole (1994), the two parties move simultaneously where the research division decides on the level of effort exerted into the development, and the financing party decides on the level of investment toward the project. As in a standard principle-agent setup, the level of effort is unobservable and non-contractable. The authors consider both the case where the financing party's investment is contractable and that where it is not. The key finding from their model is that if the research unit is given the ownership right, then it will exert an optimal level of effort, but there might be under-investment from the financing party. On the other hand, if the financing party receives the ownership right, then the research unit may not exert the optimal level of effort.

I make the same assumption as Aghion and Tirole (1994) on the non-contractibility of the innovative output due to its ill-defined nature. In addition, the action from the parties that conduct the research is non-observable and non-verifiable in both Aghion and Tirole (1994) and my model. Finally, in the case where the research division owns the IP, the value created is split in half between the financing party and the research division. Consistent with the sharing rule used in Aghion and Tirole (1994), the two subsidiaries in my model share the reward from the innovative project equally.

Rubinstein (1982) models the negotiation between two parties on the split of a pie but incorporating the utility of time. He shows that when payoff is discounted by time, the negotiated outcome is a function of the difference in the discount factor between the two parties. Because the discount factors are known constants, each party's share of the pie is a constant value. Furthermore, if the two parties have the same discount factor, then as it approaches one, the sharing rule approaches one half. One example where this could happen is when the time between offers is negligible, then the discount for that negligible time would also be negligible, as suggested in Aghion and Tirole (1994). The sharing rule being a constant (one half for simplicity) is not only an intuitive choice in the Rubinstein (1982) sense but also consistent with the industry standard. Surveying joint venture partners in practice, Caves, Crookell, and Killing (1983) and Barton, Dellenbach, and Kuruk (1988) find that equal sharing between partners is very common, and that most sharing falls between twenty and fifty percent.

Despite having similar assumptions regarding the innovation process, my model departs from Aghion and Tirole (1994) in two major ways. First, unlike in Aghion and Tirole (1994) where the financing party and the research team may be in different organizations, the headquarters and the two subsidiaries must be located in the same organization in my model. Therefore, the key purpose for a capital allocation is to coordinate actions from the two subsidiaries, and the headquarters is not only a financier but also a central planner. Second, the investment in Aghion and Tirole (1994) is used for the sole purpose of research, but in my model, once the capital is allocated to the subsidiary, the subsidiary can dedicate it to an innovative project or use it in traditional processes. Even though the use of the capital is observable, it can be used on the innovative project only if it passes through a prototype stage and enters into a production stage.

2.3.2 Multiplayer actions: Investment, effort, and capital allocation

In this thesis, I study a scenario where the headquarters is responsible for allocating capital but is not a production unit itself. The subsidiaries each make their investment decision independently. Therefore, the headquarters' capital allocation must anticipate each subsidiary's action after the subsidiary receives the capital in its choice of a project to invest. One study, Scharfstein and Stein (2000), as discussed in more detail below, provides a rationale for why capital allocation is a more effective incentive mechanism to divisional managers than a compensation contract. Similarly to the study of Scharfstein and Stein (2000), my study considers capital allocation the main tool the headquarters has to achieve coordination. However, the reason for my study is that the subsidiaries have enough autonomy to decide on an investment choice that maximizes their own subsidiary profits, as suggested in the international business literature above.

Scharfstein and Stein (2000) model a situation that explains why division managers receive capital allocation as an incentive rather than cash compensation in a two-tiered framework. The first tier is between the shareholders and the CEO, and the second tier is between the CEO and the divisional managers. The investment inefficiency is in the form of over-allocation to under-performing divisions that perhaps should otherwise be dissolved and under-allocation to over-performing divisions. This form of inefficiency cannot be simply explained by empire-building or keeping pet projects by the CEO because given limited resources the CEO themselves faces, they would still allocate to the best performing empire. The authors posit that second-tier agency concern alone cannot justify the preference of capital allocation over cash compensation. Rather, the first tier between the CEO and shareholders plays a significant role on how the CEO then addresses their agents (the subsidiary managers in my context).

Several studies examine the coordination between two parties, as discussed below. For example, Holmstrom and Milgrom (1990) model one principal and two agents in their study. The two agents work on two joint projects. Each agent decides on its own level of effort to spend on each of the two projects and incur a private cost. The agent can observe its own effort but not the effort of the other, while the principal can observe neither. However, they can observe the outcome of the project that is a function of each agent's effort into the project plus random noise.

The principal needs to decide the reward for each agent based on the outcome. Under the base case scenario, the two agents are not allowed to contract with each other, so they independently maximize their own utility. The principal maximizes a total outcome minus the payments to the agents. This serves as a benchmark. They then consider the possibility of contracting between the two agents. One agent can agree to pay the other an amount based on some decision rules. They then show that this contract results in collusion only if the decision rule concerns their private information on effort. Therefore, under certain scenarios, the principal is better off not restricting contracts between agents because they share private information with each other. However, under other scenarios, the principal is better off restricting contracts between agents to prevent collusion.

Another example is Holmstrom (1982), who models a team effort where multiple agents share the reward of the outcome of a joint project. He shows that the overall group profit cannot be maximized if the entire profit is divided up. This is because a team member can free-ride on the effort of the other members. On the other hand, when there is no guarantee that the entire profit will be split, the maximum group profit can be attained. The group can self-administer to withhold a certain portion of the profit if the maximum group profit is not attained. However, the self-administration may not effectively pose this threat. For this reason, he argues that the benefit of having a principal who manages the team is that the principal can credibly withhold a portion of the profit. He further points out that the role of the principal is solely for the coordination purpose. If the principal engages in any productive activities, then their productivity is subject to the free-rider problem again.

My study shares several similarities with these studies. First, my thesis also considers a problem that involves the actions of two independent parities. Second, the main purpose of the headquarters is to coordinate the actions of the two parties such that the overall organization profit is maximized. However, in contrast to these studies, the headquarters' capital allocation in my study must incentivize each subsidiary's investment not only in a monetary sense, but also in an intellectual sense. Furthermore, the solution proposed by Holmstrom and Milgrom (1990) focuses on the side contract between the two parties, and the solution proposed by Holmstrom (1982) is for the principal to withhold group profit. In contrast, the main mechanism in this thesis is the ex-ante capital allocation to the two subsidiaries rather than the ex-post profit split between the two parties.

2.3.3 The hold-up problem and incomplete contracts

Both the transfer-pricing literature and the literature on IP development show interest in the hold-up problem. In general, the hold-up problem arises when multiple (usually two) parties make a value-enhancing investment but at least one party invests less than its optimal level, known as the under-investment problem. The problem arises because the investing party is receiving only a portion of the its marginal profit, and it is less than its marginal cost at the optimal investment level (Williamson 1985, Schmitz 2001). Both the transfer-pricing literature and the IP development literature have considered situations where the outcome depends on the investment input of two parties. This situation is susceptible to one party making an insufficient investment, so the literature has examined how a transfer price and ownership of the developed IP could affect the hold-up problem. There are many scenarios under which the under-investment problem could occur, and the literature on the hold-up problem is rich in documenting these many scenarios and proposing solutions applicable to each.

In the context where the hold-up problem occurs within divisions of the same firm, Edlin and Reichelstein (1995) model an upstream and a downstream division of the same firm that simultaneously make a value-enhancing or cost-reducing investment that can be observable but not verifiable. The two divisions make the investment decision before the state of nature is realized. If the quantity produced that will be transferred between the two divisions and eventually sold externally and the transfer price are negotiated after the state of nature is realized, there is a hold-up problem. This is because the investment will be sunk at the time of negotiation when the divisional profit is determined. As a result, there is no guarantee that the other division will make a sufficiently large investment to render its own division's investment worthwhile. The authors propose that an upfront contract with renegotiation solves this problem. If the two divisions sign a contract that specifies a quantity and a transfer price to be traded after the state of nature is realized, there is a guarantee to both divisions that enough quantity will be traded to make their investments worthwhile. Furthermore, the renegotiation after the state of nature is realized generates only better outcomes but not worse ones. This is because the two parties can fall back to the original contract, which prevents the two divisions from being totally unprotected.

The solution proposed in Edlin and Reichelstein (1995) applies in the context of physical production, where the quantity produced is contractable. Johnson (2006) extends the work of Edlin and Reichelstein (1995) by studying the investment decision in the context of IP, where the product cannot be fully described ex-ante and thus is not contractable. In Johnson (2006), the upstream and downstream divisions sequentially invest into an intellectual property. Johnson (2006) compares and evaluates three transfer-pricing methods with respect to the hold-up problem. In the first method, the headquarters specifies a royalty rate prior to the divisions' investments and this shows that both divisions would under-invest. In the second method, the two divisions negotiate a transfer price after the first division's investment is made. With this method, the downstream division does not have a hold-up problem because its decision is made after the negotiation, so its investment is not sunk. However, the upstream division would still under-invest because its investment is sunk at the time of negotiation. The solution that Johnson (2006) proposes is with the third method that involves specifying an upfront royalty rate that is open for renegotiation after the first division's investment but prior to the second division's investment. Similar in spirit to Edlin and Reichelstein (1995), the upfront royalty rate provides protection to the first division's investment while the renegotiation provides protection to the second division's investment, thus removing the hold-up problem for both parties.

In the context of two independent parties, Hart and Moore (1988) model a seller and buyer that make simultaneous investments into an asset. Trade between the two parties occurs if the buyer's valuation of the asset exceeds the seller's cost. The buyer's valuation depends on its own investment, so does the seller's cost depend on its own investment, but the investment made by each party is not verifiable. Furthermore, the two parties cannot contract on an outcome for each state of the world that could be realized (an incomplete contract). Finally, because the investment decisions are made prior to the realization of the state, but trade occurs only after the realization, the seller's investment is unprotected, resulting in a hold-up problem.

A critical assumption in Hart and Moore (1988) is that even though the court can verify whether the trade takes place, it cannot determine the reason if there is no trade. In other words, the court cannot determine whether it is the buyer or the seller that withholds investment for no trade to occur. Nöldeke and Schmidt (1995) relax this assumption by allowing the court to verify whether a delivery is made by the seller. Under this assumption, the two parties could enter an option contract that gives the seller the right to sell the asset after their investments. Because the court could verify whether the seller makes the delivery, it could verify whether the seller exercises its option and thereby enforce the option contract. The option acts as protection to the seller's investment and resolves the hold-up problem.

Finally, Nöldeke and Schmidt (1998) approach the hold-up problem from an ownership structure perspective. Their setup involves two independent parties that make a sequential investment into an asset, but only one party owns the completed asset in the end. Traditionally, ownership by one party results in under-investment by the other party, while joint ownership results in under-investment by both parties. Nöldeke and Schmidt (1998) propose that instead of fixing the ownership choice up front, the first investor could own the asset initially, but the two parties could agree to have an option for the second investor to acquire ownership of the asset for a price. Nöldeke and Schmidt (1998) show such an option eliminates the hold-up problem (under certain assumptions), because the optimal price is high enough that the first investor is better off making an efficient investment expecting to sell the ownership later on. At the same time, the price is set such that the second investor would make an efficient investment and is better off acquiring ownership, given the first investor has made an efficient investment.

Dutta and Reichelstein (2003) combine an agent's effort with their investment decision under the principal-agent framework. In the two-period setup, an agent chooses their effort in each period and makes an investment decision only in the first period. Neither the effort nor the investment is observable. The observable cash flow for each period reflects both the current period's effort and the first-period investment. As a result, the principal cannot distinguish the effect of the effort from that of the investment. The authors show that by matching the current-period result to current-period effort, a noisy current-period signal could help the principal to disentangle the moral hazard problem from the investment problem, making this leading signal a useful performance measure to determine the agent's compensation. They further show that if a second agent is hired in the second period, the first agent does not reap any benefit from their investment in the first period and thus would under-invest. The authors show that the leading signal is necessary to resolve the hold-up problem by rewarding the first agent for their investment decision.

My model distinguishes itself from the hold-up problem in several ways. First, in my model the headquarters allocates a fixed amount of capital between two subsidiaries, so there is no under-investment from HQ's perspective. This is because the headquarters is not a production unit; in particular, any unallocated capital does not earn a return, so HQ would allocate all available capital to a project. Second, the subsidiary faces a choice between two projects, so the investment in the innovative project has an opportunity cost. The key issue in my model is not the amount of capital that each subsidiary chooses to invest, but rather the return that is realized through its choice of the project. Finally, my setup includes both a moral hazard problem and an investment problem, but the investment problem concerns the type of investment rather than the amount. The moral hazard problem in my model occurs prior to the investment decision, in contrast to Dutta and Reichelstein (2003). Furthermore, the prototype outcome allows the headquarters to incentivize effort in the first stage using an observable outcome before the investment decision.

2.4 Innovation and research and development

Innovation and research and development (R&D) is right at the intersection of the business and tax worlds. Innovation has become increasingly important to multinational corporations, and as shown in Section 2.2, the coordination of innovation processes is of special interest to the business literature. At the same time, innovation is also of special interest to the tax literature. As discussed in Section 2.1, a key consideration to tax policy-makers is the promotion of innovation and R&D, and the organization of IP can be a powerful tax-planning strategy. However, the literature has not explicitly considered the innovation processes that are critical to the success of innovation efforts. In this section, I discuss the importance of success during the early stages of an innovation project, which is the motivation for considering a prototype stage in my model.

Success during the early stages are critical to the success of innovation projects but are also most difficult to manage (Cooper 1988, 1997). For manufacturing industries, resources dedicated to these early stages account for 40% of total resources, both financial and non-financial (Cooper and Kleinschmidt 1988, Mansfield and Rapoport 1975). Innovation researchers often term these stages as the "fuzzy front-end," which is a notion first introduced by Smith and Reinertsen (1992). The front-end refers to the processes and activities prior to a massive production and a market introduction, and the term fuzzy points to the ill-defined nature of this stage. One of the challenges with new product development is that the newness of the product means that there are no existing formal processes and specifications. Studies have devoted much attention to finding best practices and factors that contribute to success during this early stage.

Khurana and Rosenthal (1997) further categorize the front-end activities into "foundation" factors that pertain to the whole organization and "project-specific" factors. They further characterize the front-end activities into three processes: opportunity identification, product conceptualization, and product definition. Surveying more than 75 managers from 11 companies that are experienced in a new product development, they find that most companies struggle with providing a clear description of the new product in these initial steps. Furthermore, they find that foundational factors play an important role in moving the innovative project forward. First, a successful innovation roots itself in a firm's overall strategy and core competence, so a clear vision from senior managers and the headquarters is vital. Second, ineffective resource allocation and coordination by senior managers is a major stumbling block to the innovation team, especially for cross-functional projects. In surveying 161 businesses that frequently engage with new product developments, Cooper (1998) reports similar findings that commitment of adequate resources, such as capital, personnel, and technology, from senior managers and m other departments that provide critical input, proves to be a key ingredient for a successful strategic plan.

The importance of success during the early stages makes prototyping appealing (Leonard and Rayport 1997, Schrage 1999). Smith and Reinertsen (1992) suggest that pilot and prototype products can facilitate the drafting of concrete plans and deadlines. Furthermore, the prototype stage allows ideas and concepts to transform into actual output. Elverum and Welo (2014) discuss three main benefits associated with prototyping. First, this step serves as a reality check to the idea-generation stage. The prototype step reveals the technical requirements and allows the innovation team to narrow down an executable plan. Second, successfully building a prototype boosts confidence among internal decision-makers and helps secure internal financing. This step reduces the uncertainty associated with the realization of the idea and allows the innovation team to present a more convincing case. In addition to securing internal financing, Audretsch, Bönte, and Mahagaonkar (2012) document that a successful prototype also increases the likelihood of obtaining an external financing. Third, prototyping provides a great learning opportunity for the innovation team, to gain a deeper understanding of the project and a deeper appreciation for each other. Thomke (1998) documents that innovation teams garner more extensive learning from iterative prototypes.

In a case study, Bogers and Horst (2014) find that collaborations during the prototype stage help translate vague ideas into a detailed product specifications. Furthermore, the collaborative input enhances the functionality and marketability of the prototype. In the context of customization for external customers, Terwiesch and Loch (2004) show that eliciting customers' input in reviewing prototypes allows the design team to better understand customers' desires that are otherwise difficult to communicate absent a prototype. Bogers and Horst (2014) further document that cross-functional collaborations during the prototype stage allow input from different functions and foster cross-functional learning and communication. Finally, cross-functional collaborations provide flexibility over the design process, which has been shown to reduce the risk of failure (Thomke 1997). Activities that involve multiple functions typically require formal structured steps and are time-consuming. However, cross-functional collaborations provide the advantage of a flexible sequence of steps and a shorter wait time between each step.

Collaborations during the prototype phase are not only critical to providing the complete set of expertise required but are also critical to knowledge-sharing and organizational learning. Mascitelli (2000) focuses on "breakthrough" innovations that are original and involve a high level of creativity. These innovations often generate a competitive advantage that leads to sustaining profitability and a stable market share. Mascitelli (2000) posits that the most important aspect to this type of innovations is "tacit knowledge" (p. 181), the subtle intuition that lies beneath the "conscious thoughts" (p. 181) that results from the accumulation and integration of knowledge, information, and through experiences.

Given the importance of tacit knowledge to breakthrough innovations, organizations are interested in developing this asset among innovation teams. Research on tacit knowledge shows that education and formal training are not effective methods of acquiring and sharing tacit knowledge. Rather, in-person interactions through research collaborations are more effective at promoting the sharing of tacit knowledge. This aspect of tacit knowledge makes subsidiary-specific expertise less mobile (Sheng and Hartmann 2019). Furthermore, tacit knowledge is difficult to test and is generally not observable, further supporting the argument that intellectual contribution is a hidden action (Spender and Grant 1996, Gibbons 1994). Finally, Mascitelli (2000) finds that prototyping activities provide an ideal platform for the transfer of tacit knowledge through experiences and personal interactions.

The importance of cross-functional collaborations motivates the setup in my model where the two subsidiaries each possesses a different expertise, and the innovative opportunity can be pursued if both subsidiaries contribute to the innovative project. The importance of managing the early stages of an innovation process motivates the inclusion of a prototype stage. As discussed in Chapter 4, the innovative project faces a risk of failure during the prototype stage, and it cannot move into the production stage unless it first succeeds at the prototype stage. Finally, intellectual contributions from both subsidiaries are required for the prototype to succeed.

Chapter 3. Base Model

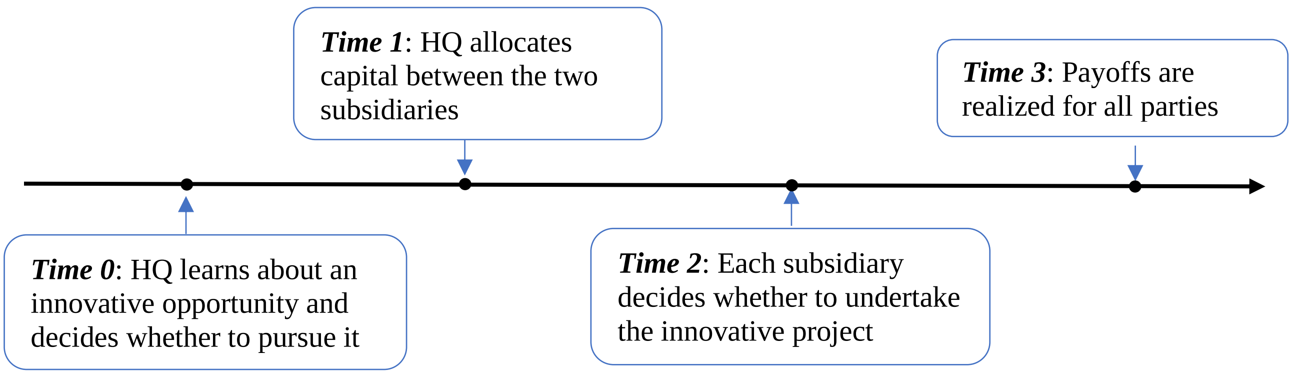
3.1 Model Setup

As with standard models, my model has a multinational corporation (MNC) that has a headquarters (HQ) and two wholly owned international subsidiaries, denoted respectively as H and L. The location of HQ is not critical in my model, but the locations of the two subsidiaries are. Namely, subsidiary H operates in in a high-tax jurisdiction that charges a corporate tax rate of $\tau + h$ where $h > 0$, while subsidiary L operates in a low-tax jurisdiction that charges a corporate tax rate of τ. In the base case, the tax differential between the two subsidiaries is denoted as h. To study the effect of an exogenous tax event, in Chapter 5, the model considers the introduction of a tax cut from a high-tax country that reduces the tax differential from h to k.

The model has three players, the headquarters and the two subsidiaries, that are involved in a sequential game with the following timeline. At *Time 0*, HQ has a certain amount of capital (λ) to be allocated. It identifies an innovative opportunity and learns about its prospect in terms of a pre-tax return $\beta + \gamma$, where γ is the profitability the innovative opportunity generates incrementally to the existing process that earns a baseline return of β. This innovative opportunity requires each subsidiary to contribute its own unique expertise. At this point, HQ decides whether the innovative opportunity is worth pursuing. If HQ pursues the opportunity, then it incentivizes the two subsidiaries to collaborate on the innovative project through its capital allocation between the two subsidiaries. On the other hand, if HQ chooses not to pursue the opportunity, then the capital allocated to each subsidiary goes to the subsidiary's traditional production. Its objective is then to maximize the total group payoff.

After HQ allocates λ^H and λ^L to the high-tax and low-tax subsidiaries, respectively, the two subsidiaries move simultaneously and decide whether to undertake the innovative opportunity, with each subsidiary maximizing its own payoff. Once a subsidiary makes its choice, both the capital allocated to the subsidiary and any subsidiary-specific resources that are relevant to the project will be devoted to the project of the subsidiary's choice. If a subsidiary chooses not to contribute to the innovative project, its default is to continue with traditional processes. In this case, the subsidiary earns a return of β and keeps all the profits. On the other hand, the innovative opportunity earns a higher return of $\beta + \gamma$, but the two subsidiaries must share the total reward from the innovative project. Figure 1 depicts the timeline of events.

Figure 1. Model timeline



This setup captures the horizontal structure of the MNC where each subsidiary is endowed with its own subsidiary-specific expertise, and the success of the innovation requires both sets of expertise. When both subsidiaries choose the innovative project, they work together and share their respective expertise on the common project. HQ could use capital allocation to coordinate an outcome where both subsidiaries participate in the innovation. When the capital allocation provides an incentive for both subsidiaries to contribute their knowledge to the innovative project, knowledge-sharing occurs among the subsidiaries through their collaboration.

To illustrate the advantage of an internal collaboration in the process of innovation, I provide a stylized example below. Suppose that a firm is in the healthcare industry and one of its hospital clients approaches the firm for a new patient-monitoring technology. If the firm can successfully deliver the technology, not only will it win the contract with the hospital, but also the pilot-testing at the hospital will significantly enhance the success of commercializing the product for senior homes in the future. Suppose that the Canadian subsidiary has data and knowledge on patient behavior, but the U.S. subsidiary has the machine-learning technique of picture processing. The new technology aims at accurately detecting motion and alerting about abnormal behaviors. The success of the new product requires adapting a picture processing technology to a patient behavior, which represents a combination of the expertise from both subsidiaries.

At the time of the capital allocation, HQ cannot dictate the project choice made by the subsidiaries. As discussed in my review of the literature, if a subsidiary develops and owns special knowledge (Birkinshaw 1997, Birkinshaw, Hood, and Jonsson 1998), then the knowledge is accessible by other members of the organization only if the subsidiary willingly shares it (Cantwell and Mudambi 2005, Rugman and Verbeke 2001). This is because the tacit nature of knowledge presents difficulties for HQ to manage it through formal processes. Because the intellectual contribution from the subsidiary is both unobservable and unverifiable, it is impossible to write formal contracts on it (Beaudry and Schiffauerova 2011, Katz and Martin 1997, Gnyawalị, Singal, and Mu 2009, Leiponen and Helfat 2010, Regnell et al. 2009). Second, the literature generally considers it difficult to trace the use of capital for one purpose versus another (Dutta and Reichelstein 2003, Hart and Moore 1988, 1999, Johnson 2006). In the stylized example above, if the Canadian subsidiary spends money to recruit patients for more data, it is difficult to verify or refute whether it uses the experimental result for the purpose of innovation.

The tacit nature of knowledge also presents challenges to use other control systems. First, because the intellectual contribution must occur before a product is developed, it is invisible and ill-defined, making it non-transferrable (Zander and Kogut 1995, Mascitelli 2000), so the problem cannot be solved with a traditional transfer-pricing model (Baldenius, Melumad, and Reichelstein 2004, Choe and Hyde 2008, Hiemann and Reichelstein 2012, Hirshleifer 1956).[3] Furthermore, direct involvement by HQ in a creative taskforce is generally not advisable. Studies document that teaming up subsidiaries to engage in activities together is an effective way to facilitate knowledge-sharing, but giving direct orders is not effective (Hedlund 1994, Subramaniam and Venkatraman 2001, Mahnke and Venzin 2003, Mahnke, Venzin, and Zahra 2007). Furthermore, behavioral research documents that creativity must be self-initiated and can be hindered by direct monitoring (Kachelmeier, Reichert, and Williamson 2008, Kachelmeier and Williamson 2010, Amabile et al. 1996, Amabile and Pratt 2016, Grabner 2014), further limiting HQ's interventions through monitoring (Son, Cho, and Kang 2017).

The setup in Rajan, Servaes, and Zingales (2000) motivates the setup in my model. Although the focus of Rajan, Servaes, and Zingales (2000) is quite different from mine, the structure of their model appeals to the problem I intend to study. The focus of their paper is to explain the reallocation of capital from a less profitable division to a more profitable one, whereas my focus is on the distortion that taxation creates in the subsidiaries' preferences toward a collaboration opportunity that influences how an MNC responds to tax incentives with regard to its capital allocation. In my setup, the pre-tax return is the same across the two subsidiaries, so tax is the only factor that contributes to the difference in the after-tax returns between the two subsidiaries.

[3] It also means that the headquarters cannot purchase the necessary expertise from each subsidiary and then combine the expertise to conduct the innovation itself.

Suppose that HQ pursues the innovative project, then its capital allocation must induce both subsidiaries to choose the same project. HQ's capital allocation decision can be described with the following linear program LP-Base, where HQ maximizes total payoff, but each subsidiary maximizes its own payoff.

(LP-Base):

$$\max_{\lambda^H,\lambda^L} \ (\beta+\gamma)\big((1-\tau-h)\lambda^H+(1-\tau)\lambda^L\big)$$

subject to

$$(1-\omega)(\beta+\gamma)\big((1-\tau-h)\lambda^H+(1-\tau)\lambda^L\big) \geq \beta(1-\tau-h)\lambda^H \ \ (1)$$

$$\omega(\beta+\gamma)\big((1-\tau-h)\lambda^H+(1-\tau)\lambda^L\big) \geq \beta(1-\tau)\lambda^L \ \ (2)$$

$$\lambda^H+\lambda^L=\lambda \ (3)$$

$$\lambda^H,\lambda^L \geq 0 \ (4)$$

If HQ induces both subsidiaries to choose the innovative project, then the project earns a return of $\beta+\gamma$, where β is the baseline return on the existing production and γ is the incremental return earned by the innovative effort. The total capital allocated toward the innovative project is λ, but it is allocated to the two subsidiaries. Profit earned from the capital allocated to the high-tax subsidiary λ^H is subject to the high-tax jurisdiction's tax rate of $\tau+h$, and profit earned from the capital allocated to the low-tax subsidiary λ^L is subjected to the low-tax jurisdiction's tax rate of τ, so the tax-rate differential between the two jurisdictions is h. The tax consequences are strictly determined by the capital contribution of each party. This is consistent with the practice of many tax authorities that determine the appropriate taxable income in each jurisdiction based on the investment made in that jurisdiction.

Inequality (1) is the incentive-compatible constraint for the high-tax subsidiary, and inequality (2) is the incentive-compatible constraint for the low-tax subsidiary. These constraints ensure that the payoff for joining the collaboration exceeds the payoff for working alone for both subsidiaries. The right-hand-side (RHS) of inequality (1) represents the payoff that the high-tax subsidiary earns by working alone, and equals the baseline return β that it earns with its traditional processes, multiplied to its capital investment of λ^H, after paying taxes at a rate of $\tau + h$. The left-hand-side (LHS) of inequality (1) represents the payoff that the high-tax subsidiary earns by collaborating on the innovative project and is simply its share of the total after-tax payoff. Similarly, the LHS of inequality (2) represents the payoff that the low-tax subsidiary earns from collaborating on the innovative project.

The two subsidiaries negotiate with one another regarding each party's share of the total reward from the joint project before HQ makes its allocation decision. The total reward available to share is the net profit after paying all expenses and relevant taxes. The parties negotiate based on the intrinsic value perceived by each party of its intellectual contribution with its respective bargaining power. Furthermore, because the negotiation occurs prior to the capital allocation, this negotiation cannot refer to the capital contribution but solely to the intellectual contribution. This setup is similar in sprit to Halperin and Srinidhi (1991) who study the effect of internal transfer-pricing between two parties on their production decisions. Citing several other studies, Halperin and Srinidhi (1991) maintain that having the two parties negotiate the split of the after-tax pie achieves a higher firm value than having HQ dictate a split.

As discussed in Aghion and Tirole (1994) and shown in Rubinstein (1982), when the two subsidiaries have similar bargaining power, a split of one half will be reached under a Nash bargaining process. I do not explicitly model this process but take the outcome of the process as given. Let the bargaining outcome be $\omega \in (0,1)$ that is the low-tax subsidiary's share and $1 - \omega$ that is the high-tax subsidiary's share. Furthermore, both subsidiaries bring an important and valuable intellectual contribution, so their split must be within a reasonable range. Although it is not possible to price these contributions, each subsidiary contributes an irreplaceable part of the innovation process. In other words, $\omega \in [\underline{\omega}, \overline{\omega}]$, with both the lower and upper bounds $(\underline{\omega}, \overline{\omega})$ strictly between 0 and 1.

The most important assumption in my setup regarding ω is not whether the two subsidiaries bargain for it or HQ assigns it, but rather that it must be within a reasonable range. Although it is not possible to price or transact these intellectual contributions, each subsidiary has an intrinsic value that it assigns to its own contribution, especially when the expertise is developed within the subsidiary. Furthermore, because each subsidiary's contribution is both irreplaceable and indispensable to the innovation process, each must receive a reasonable share for its contribution.

I note two observations about this process. First, this split does not refer to the capital allocation from HQ because they are two different types of resources that are managed in different ways. Capital is centrally owned and can be easily transferred, whereas knowledge is locally owned and is not easily transferrable. HQ cannot force upon the local owner of the knowledge as to how it ought to value and use its knowledge. However, it could use the transferrable resource to coordinate the sharing of the non-transferal resources. Second, from the subsidiary's perspective, even though it can enforce the sharing of the reward through interventions by HQ, it cannot enforce the investment choice made by the other subsidiary. Once the capital has been allocated, it is impossible to trace and verify the use of capital for one purpose versus another.

Equation (3) captures the budget constraint where the allocation between the two subsidiaries adds up to the total budget available for the innovative project. Here, λ represents the total capital that HQ sets aside for this specific project. Because only the two subsidiaries have the expertise relevant to the project, the capital is allocated between only these two subsidiaries. What matters in this setup is not the amount of capital to be allocated but rather the split between the two subsidiaries of whatever is available. This means that any unallocated capital from this project earns a zero return, so the budget constraint is at equality. Finally, equation (4) captures the non-negativity constraint.

3.1 Model Solution

Proposition 1 the solution to LP-Base is the following:

1. If $\gamma \geq \frac{1-\omega}{\omega}\beta$, $(\lambda^H, \lambda^L) = (0, \lambda)$
2. If $\gamma \leq \frac{1-\omega}{\omega}\beta$, $(\lambda^H, \lambda^L) = (\lambda - s_L, s_L)$, where

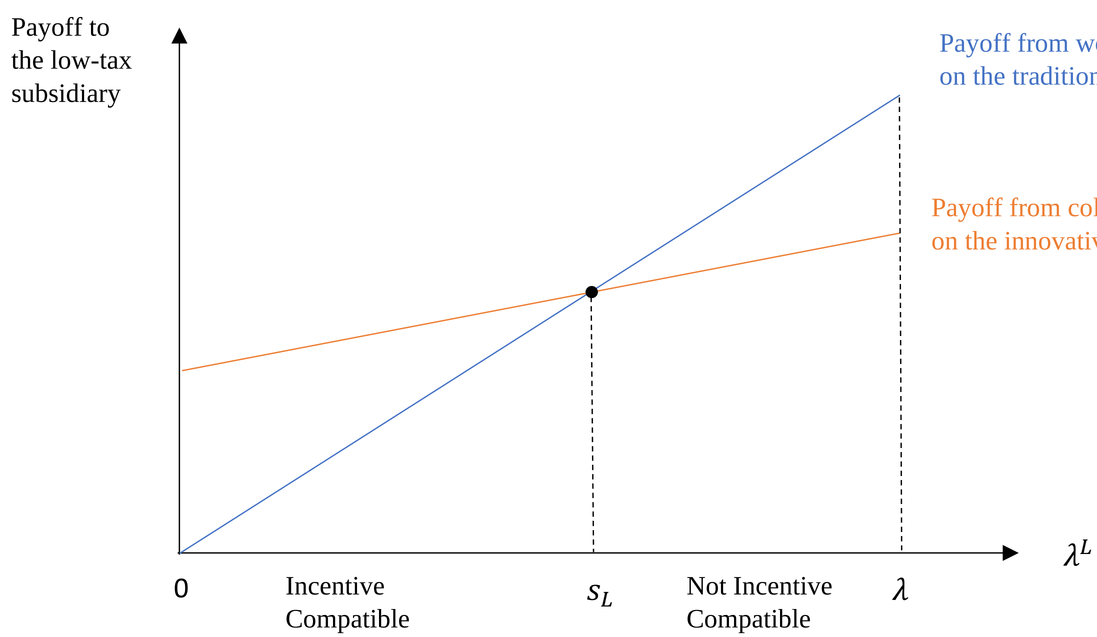
$$s_L = \frac{\omega(\beta+\gamma)(1-\tau-h)}{\beta(1-\tau)-\omega(\beta+\gamma)h}\lambda$$

This solution is the optimal allocation if HQ chooses to induce collaboration. This is not the final solution yet because HQ still needs to compare the benefit of including collaboration with the tax cost associated with it. The next proposition discusses this comparison.

To understand this result, note that the most tax-efficient allocation is to allocate all the capital to the low-tax subsidiary. However, this allocation is not always incentive-compatible for the low-tax subsidiary to collaborate on the innovative project. This is because although the innovative project earns a higher return, the payoff from its capital investment must be shared with the high-tax subsidiary. On the other hand, by not collaborating on the innovative project, the low-tax subsidiary keeps all the profits it earns from its traditional project. This presents us with two scenarios. First, if the incremental return on the innovative project is so high that it offers a higher payoff even after sharing, then the low-tax subsidiary will choose to work together no matter what the capital allocation is. The first case of Proposition 1 captures this scenario. Second, if the incremental return is not high enough, then allocating all the capital to the low-tax subsidiary is not incentive-compatible. In this case, HQ would allocate the maximum amount of capital to the low-tax subsidiary while preserving its incentive-compatible constraint. This maximum amount is s_L as stated in the second case of Proposition 1.

The key insight here is that a subsidiary cannot be allocated too much capital. As illustrated in Figure 2, to the low-tax subsidiary, working together is appealing when its capital allocation is high but unappealing when its capital allocation is low. The party that welcomes a sharing arrangement is the one that brings little but receives much. This occurs when the capital allocation is low. The payoff that it can earn from its own low amount of capital is low, but the payoff it shares from working together is high. On the other hand, the party that opposes a sharing arrangement is the one that brings much but receives little. This occurs when the capital allocation is high. In this case, the payoff it can earn from its own capital is high, but the payoff it shares from working together is low.

Figure 2. Illustration of incentive-compatible allocation



I make several observations regarding s_L. First, the tax-rate differential between the two subsidiaries exacerbates the problem. One can see this effect by observing that s_L decreases in h. In other words, the low-tax subsidiary is more likely not to collaborate when the tax-rate differential between the two subsidiaries is high. To see this result, suppose that the capital is allocated equally between the two subsidiaries. Without a tax-rate differential, sharing would be equally appealing to both subsidiaries. However, when the two subsidiaries are subject to different tax rates, sharing is no longer equally appealing to both. The low-tax subsidiary has more after-tax profits to offer and thus finds sharing (through collaboration) with the high-tax subsidiary less appealing. The higher the tax differential is, the less appealing collaboration becomes to the low-tax subsidiary. Therefore, from the subsidiaries' perspective, the tax-rate difference is not neutral to their incentives toward working together on the efficient project.

Second, the problem is less severe if the low-tax subsidiary shares a higher portion of the total after-tax pie, and one can see this by observing that s_L increases in ω. A higher ω increases the payoff for collaborating on the innovative project and makes this project more appealing. This allows the low-tax subsidiary to favor the sharing arrangement even if it is given a higher amount of capital. Third, a higher incremental return offered by the innovative project mitigates the problem, and one observe that s_L increases in γ. A higher return makes collaborating on the innovative project more appealing and allows a higher amount of capital to be allocated to the low-tax subsidiary while maintaining its preference for the innovative project. In fact, when γ is so high, one is back to the first case where the low-tax subsidiary prefers collaborating on the innovative project regardless of the amount of capital it receives. Finally, a higher return offered by the traditional process exacerbates the problem, and one can observe that s_L decreases in β. A higher β makes working alone more attractive relative to working together, and the rationale is exactly the opposite to that for γ. Table 1 summarizes the above discussion.

Table 1. Effect of increase in parameters on the maximum incentive-compatible allocation

Increase in parameter	Description of parameters	Effect on s_L
h	Tax-rate differential between the high- and low-tax subsidiary	decrease
ω	The low-tax subsidiary's share of the total reward from collaborating on the innovative project	increase
γ	The incremental profitability on the innovative project that must be worked on together	increase
β	The baseline profitability on traditional processes that can be completed alone	decrease

Proposition 2

If $\gamma < \frac{(1-\omega)h}{(1-\tau-h)+\omega h}\beta$, inducing collaboration is not worthwhile, and $(\lambda^{H*}, \lambda^{L*}) = (0, \lambda)$.

If $\gamma > \frac{(1-\omega)h}{(1-\tau-h)+\omega h}\beta$, HQ induces collaboration, and the optimal allocation is:

1. $(\lambda^{H*}, \lambda^{L*}) = (0, \lambda)$ if $\gamma > \frac{1-\omega}{\omega}\beta$
2. $(\lambda^{H*}, \lambda^{L*}) = (\lambda - s_L, s_L)$ if $\frac{(1-\omega)h}{(1-\tau-h)+\omega h}\beta < \gamma < \frac{1-\omega}{\omega}\beta$.

The final allocation depends on whether inducing collaboration is worthwhile. When γ is so high that even the tax-minimizing allocation is incentive-compatible, there is no tax cost associated with inducing collaboration. This is the first-best scenario where HQ achieves both the maximum tax savings and coordination toward collaboration. However, when the first-best solution is not available, there is a tax cost associated with coordinating toward collaboration. To induce collaboration, HQ must allocate capital to the high-tax subsidiary and pay higher taxes on the return earned with this capital. HQ trades off the benefit of collaboration against the tax costs associated with it. If it is too costly to induce collaboration, then HQ will optimally forgo collaboration and focus only on the tax-planning objective. Case 2 of Proposition 2 describes this case.

On the other hand, if the benefits outweigh the tax costs, HQ induces collaboration at the lowest tax cost. The objective to coordinate the two subsidiaries to collaborate on the efficient project interacts with the tax-planning opportunities to create an interior solution. As shown in Proposition 1, HQ allocates as much capital as possible to the low-tax subsidiary while maintaining its preference for working together on the innovative project over working alone on the traditional project. The optimal allocation therefore is to allocate s_L to the low-tax subsidiary and the remaining amount to the high-tax subsidiary, where s_L is the point above which the low-tax subsidiary flips its preference.

Note that the tax-rate differential between the two subsidiaries is not "tax-neutral" from the perspective of HQ's capital allocation, and it reduces the set of optimal allocations that support internal collaborations. First, without the tax-rate difference, HQ would always induce the two subsidiaries to work together on the efficient project. However, because of the tax cost associated with the tax-rate differential, collaboration is not always worth inducing. Second, without the tax-planning opportunities, the MNC would be indifferent among all allocations that induce collaboration. However, the tax-rate difference causes HQ to prefer allocations that favor the low-tax subsidiary.

In summary, the base model illustrates the tradeoff between a multinational corporation's tax-planning objective and its coordination objective. The base model considers a situation where an innovative opportunity requires expertise from two subsidiaries. The capital allocation could coordinate the outcome where both subsidiaries choose to participate in the innovation project. However, the allocation that achieves the coordination purpose does not always minimize taxes.

Chapter 4. Model Extension

In Chapter 3, I develop a base model that does not separate the development stage from the production stage of an innovation project. Hence, it combines the subsidiary's intellectual contribution decision with its investment decision. Furthermore, the base model assumes no risk associated with the innovation project. To better reflect the reality of an innovative process, I introduce a prototype stage that allows subsidiaries to test ideas before moving into mass production. Prototyping is a common step in many innovation processes because of its benefits to managing the fuzzy front-end. Typically, an innovative project does not move into the production stage unless it first succeeds at the prototype stage. This encourages the innovation team to develop concrete ideas before going too far with its resources.

Introducing a prototype stage expands the model in several ways. First, the return on the innovative project is no longer assumed to be risk-free. The probability of failure at the prototype stage reflects the risky nature of an innovative endeavor. Second, the prototype stage can produce an observable outcome. If success can be clearly distinguished and verified from failure, then the capital allocation can depend on the prototype outcome. This allows me to compare the case when the prototype outcome is contractable versus when the prototype outcome cannot be distinguished or verified. Finally, the critical input during the prototype stage is the intellectual contribution from both subsidiaries. However, the soft nature of the intellectual contribution prevents it from being observable or verifiable. On the other hand, the critical input during the production stage is capital investment. This setup separates a subsidiary's decision to contribute intellectual resources from its decision to invest capital resources, allowing me to disentangle the two incentive problems and to further relax assumptions about the investment decision.

4.1 Model Setup

The corporate structure follows the setup in the base model in Chapter 3 where a multinational corporation (MNC) has a headquarters office and two wholly owned international subsidiaries, denoted as H and L, respectively as before. Subsidiary H is located in a high-tax jurisdiction with a corporate tax rate $\tau + h$ where $h > 0$, while subsidiary L is located in a low-tax jurisdiction with a corporate tax rate τ. In the base case, the tax differential between the two subsidiaries is h. A tax cut that reduces the tax rate differential from h to k will be introduced in Chapter 5 to study how the capital allocation changes following a tax cut.

The three players are the headquarters and the two subsidiaries, as in the base model, but they engage in a sequential game with the following modified timeline. At *Time 0,* HQ identifies an innovative opportunity and learns about its prospect in terms of its pre-tax return of $\beta + \gamma$, where γ is the profitability the innovative project generates incrementally to the traditional production that earns a pre-tax return of β. At this time, HQ decides whether the innovative opportunity is worthwhile pursuing. It compares the tax cost associated with inducing collaboration on the innovative project with the incremental benefit of the project. HQ moves again at *Time 1* and decides on the capital allocation. Model 1 extends the base model in the following way. HQ allocates the capital upfront just as in the base model, but the innovative project faces a risk of failure at the prototype stage. The upfront allocation assumes that the prototype outcome cannot be contracted upon. In Model 2, I relax this assumption and allow the prototype outcome to be observable and verifiable, so that HQ's *Time 1* decision entails an upfront contract that specifies a set of capital allocations for each prototype outcome. Figure 3.1 depicts the timeline for Model 1 and Figure 3.2 depicts the timeline for Model 2.

Figure 3 Timeline of events

Figure 3.1 - Upfront allocation and unverifiable prototype outcome

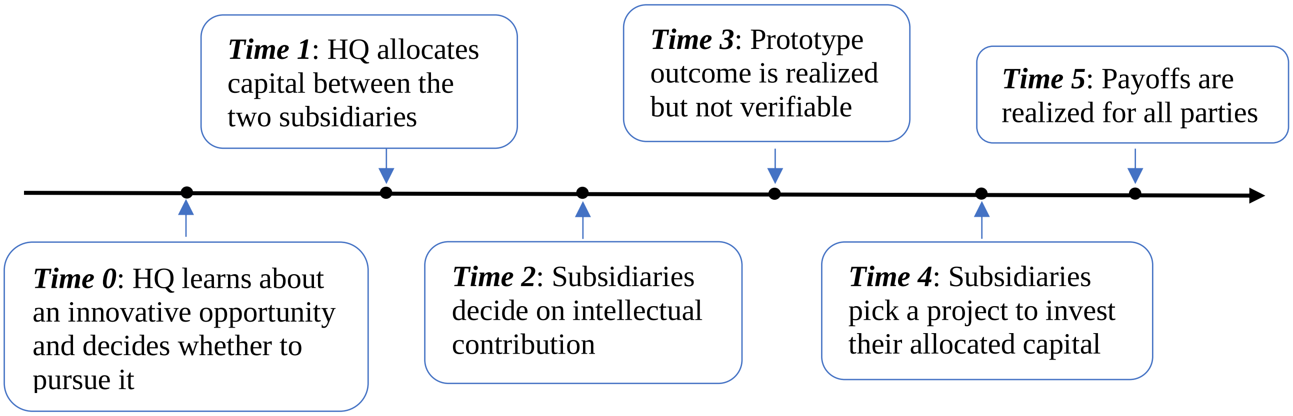
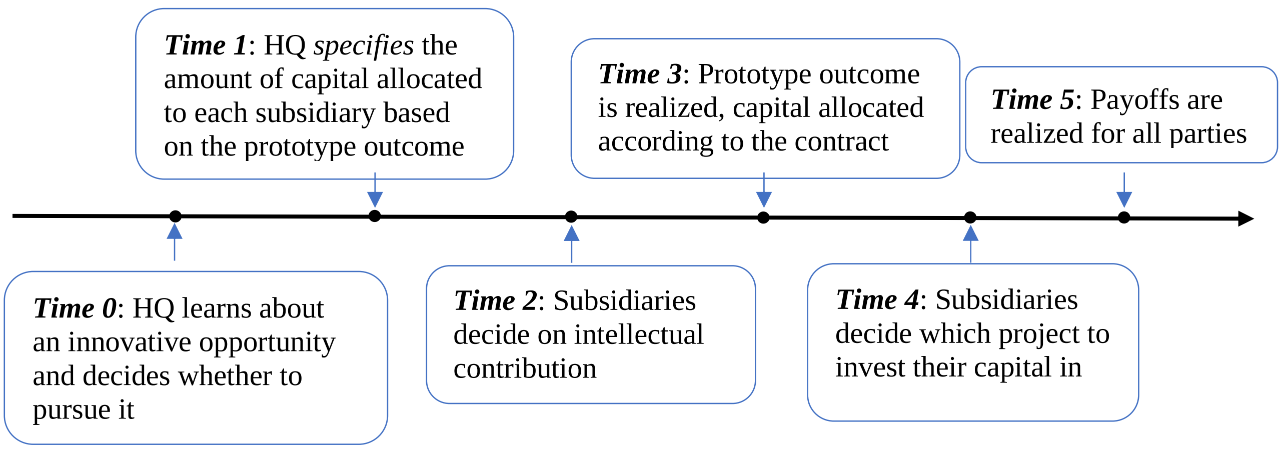


Figure 3.2 - Upfront contract and verifiable prototype outcome



Prototype stage: The Time 2 intellectual contribution

After learning about HQ's capital allocation decision, the two subsidiaries decide at *Time 2* whether to contribute intellectually, so the intellectual contribution occurs during the prototype stage. The nature of R&D activities varies greatly, from the less concrete stages, such as problem identification that involves information-gathering and idea-generation, to more concrete stages, such as implementing a solution to the problem. The prototype stage occurs when the innovation team identifies a possible solution and implements it in the production of a sample product. Badri et al. (1997) describe the R&D process as an interactive one between problem identification and prototype development. Several studies recommend starting the prototype stage early because it allows the innovation team to conduct feasibility tests and turn abstract ideas into executable plans (Audretsch, Bönte, and Mahagaonkar 2012, Elverum and Welo 2014). Studies also show that the product development stage accounts for 40% of total innovation expenditures for manufacturing industries (Cooper and Kleinschmidt 1988, Mansfield and Rapoport 1975). It is also the prototype stage that requires the most contribution of expertise and intellectual capacities from the team members.

In the model setup, success during the prototype stage requires expertise from both subsidiaries, and is doomed to fail if either of the subsidiaries withholds its expertise. If both subsidiaries contribute intellectually during the prototype stage, then the prototype has a probability of p to succeed and a probability of $(1 - p)$ to fail. On the other hand, if a subsidiary chooses not to contribute intellectually, the prototype will surely fail. The setup has two implications. First the intellectual contributions from *both* subsidiaries at the prototype stage are critical to the success of the project. Second, when the prototype fails, one cannot distinguish whether the failure is due to a subsidiary withholding its expertise or simply due to chance, even after both subsidiaries provide their expertise. In other words, each subsidiary's intellectual contribution is a hidden action, and there is no direct link between a subsidiary's action and an observable outcome.

The intellectual contribution is not contractable for several reasons. First, as discussed in Aghion and Tirole (1994) and Johnson (2006), the intellectual input is difficult to specify. The ill-defined nature of an innovative endeavor precludes HQ from specifying a certain outcome on which a penalty can be imposed if it is not achieved by the subsidiaries. The input is especially ill-defined during the prototype stage, during which the exact input required is not clear even to the team members themselves (Regnell et al. 2009, Beaudry and Schiffauerova 2011). Second, because the intellectual contribution from each subsidiary takes the form of knowledge and expertise, it is usually not observable (Gnyawali, Singal, and Mu 2009, Leiponen and Helfat 2010). Third, even in situations where some soft information might be observed, the subsidiary's intellectual contribution is usually not verifiable by a third party. A supervisor may observe a brainstorming session and still cannot tell whether a team member is withholding knowledge and expertise (Farris 1972). Furthermore, subjective evaluations from team members often contain self-serving biases that reflect mere feelings and personal preferences (Flynn 2006). Finally, a direct monitoring could hinder the creative process. Behavioral theory suggests that an innovative effort must be self-initiated, so quantity-based and extrinsic incentives are generally ineffective (Kachelmeier, Reichert, and Williamson 2008, Kachelmeier and Williamson 2010, Amabile et al. 1996, Amabile and Pratt 2016, Grabner 2014, Son, Cho, and Kang 2017).

The setup implicitly assumes that HQ is somewhat familiar with the innovation process, so is knowledgeable about the feasibility and marketability of the innovation project. HQ can learn about the prospect of the innovative project independent of the subsidiary's actions. In organizations where HQ acts as the strategic leader in the innovation process, HQ is knowledgeable about the innovation opportunities and can be the initiator of the process. In other organizations however, HQ can heavily rely on innovation elicitation from subsidiaries, and the subsidiaries' choices of whether to contribute intellectually could affect HQ's ability to learn about the innovative opportunity. In my setup, HQ understands the distribution of knowledge among its subsidiary network and is in the best position to identify innovative opportunities. Furthermore, it also understands the risk associated with the innovative opportunity, so the probability of success is public knowledge.

Prototype stage: The Time 3 realization

After each subsidiary makes the decision regarding its intellectual contribution, they start developing the prototype. If the prototype succeeds, then the innovation project moves to the production stage. If the prototype fails, then the innovation project is scrapped. As discussed in the literature review section, the early stages of the innovation process is critical to successful delivery of the innovation product to the market (Smith and Reinertsen 1992, Cooper 1997, Cooper and Kleinschmidt 1987, Kim and Wilemon 2002), and experimenting during the prototype stage allows the innovation team to solidify ideas and test design feasibility (Elverum and Welo 2014, Bogers and Horst 2014). If the project does not meet the technical requirements during the prototype stage, then it is not feasible for a massive production.

The model allows the prototype outcome to be observable by all three parties. The two subsidiaries that are directly involved in the prototype effort can certainly observe its outcome, and HQ can request a demonstration of the progress made. However, whether the outcome is a success or a failure can be subjective and difficult to verify. In situations where a success can be clearly distinguished from a failure, the prototype outcome is verifiable. For example, a new drug must pass a certain number of trials to be considered a success, or a contract with the hospital requires the hospital's approval of an initial demonstration. On the other hand, in situations where the line between success and failure is blurry, the prototype outcome is not verifiable. For example, a movie team may present its idea through a synopsis and receive an evaluation, but the evaluation can be very subjective as beauty is in the eye of the beholder, or a software team could produce a functional program, but it could be extremely user-unfriendly.

In Model 1, I assume that the prototype outcome is not verifiable, so the capital allocation cannot depend on it. In this case, HQ allocates capital upfront as with the base model but faces a risk of failure for engaging in innovation. Model 2 relaxes this assumption and allows the prototype outcome to be verifiable, so the capital allocation can depend on it. I present the formulation and result for each setup and discuss advantages and disadvantages in the model comparison section.

Time 4 Investment

After the prototype outcome is realized, the subsidiaries make their investment decisions with the amount of capital allocated from HQ. If the project fails at the prototype stage, then the innovative opportunity vanishes, and the only investment option is traditional production. Because the traditional project is well-established, it earns a return of β. Furthermore, the traditional project can be completed alone, and the return does not depend on the other subsidiary's investment choice. On the other hand, if the project succeeds at the prototype stage, then the subsidiary has a choice of whether to invest its capital into the innovative or into the traditional project. The innovative project earns a return of $\beta + \gamma$ only if both subsidiaries invest their capital in the innovative project. If one subsidiary does not invest in innovation, it is not beneficial for the other subsidiary to invest in innovation either, because it cannot complete the innovative project alone. Therefore, from HQ's perspective, the capital allocation must incentivize both subsidiaries to invest in innovation.

The prior literature generally considers investment decisions to be non-contractable, because the complete states of investment outcomes are difficult to specify ex-ante and impossible to verify (Johnson 2006, Grossman and Hart 1986, Myers 1977, Rajan, Servaes, and Zingales 2000). Furthermore, a subsidiary often makes many investments and engages in numerous activities, so it is difficult to separately track the activities for each investment (Dutta and Reichelstein 2003). In the context of managing foreign subsidiaries, studies have found that formal contracts are less effective at governing intangible assets than tangible assets (Galbraith and Kay 1986, Morrison and Roth 1992). The literature generally documents a lack of visibility on the subsidiary's investment decision, especially in organizations where subsidiaries are dispersed both geographically and functionally (Roth and O'Donnell 1996, Bartlett 1998, Ghoshal and Nohria 1989). In organizations where the interdependence is low among subsidiaries, it might be possible to establish a direct relationship between the subsidiary's decision and a specific outcome, especially if the subsidiary is responsible for a single step within a supply chain (Ghoshal and Bartlett 1990, Ghoshal and Nohria 1994). In such organizations, the investment decision might be observable, but it remains unclear whether the investment decision is verifiable by court.

In Model 4, I further relax this assumption and allow the *Time 4* investment decision to become contractable. If HQ can track each subsidiary's investment and verify its return, then once it observes the prototype's success, it can tell whether a subsidiary has made an investment in the innovative project. Once the prototype succeeds, if a subsidiary's investment earns only the baseline return, then HQ knows that the subsidiary has not invested in innovation. In that case, HQ could specify different amounts of allocation based on the investment outcome it observes once the prototype succeeds. Permitting the *Time 4* investment to become contractable essentially eliminates the *Time 4* incentive problem, because HQ could penalize the subsidiary that does not invest in innovation after the prototype has succeeded.

Table 2 summarizes the features for each model extension and illustrates the progression of each model extension in relaxing the assumptions one at a time. The base model has none of the additional features. Model 1 introduces a risk of failure of the innovative project while holding other features the same. Model 2 further relaxes the assumption and allows the prototype outcome to become observable by HQ and verifiable. Model 3 builds upon Model 2 and further relaxes the budget constraint, so that HQ needs not allocate all the available capital to the subsidiaries. In addition to allowing the above features, Model 4 also allows the *Time 4* investment to become contractable, and thus is the most general version of all of the models considered in this thesis.

Table 2. Progression of Relaxing Assumptions by Model Extensions

	Innovation Risk	Prototype Outcome Contractable	Relax Budget Constraint	*Times 4* Investment Contractable
Base Model	No	No	No	No
Model 1	Yes	No	No	No
Model 2	Yes	Yes	No	No
Model 3	Yes	Yes	Yes	No
Model 4	Yes	Yes	Yes	Yes

4.2 Model Solution and Discussion

To determine whether the innovative opportunity is worthwhile pursuing at *Time 0*, HQ must know its expected payoff if it induces both subsidiaries to collaborate on the innovative opportunity, and then compares it to the expected payoff if it forgoes the innovative opportunity. As with the base model, HQ must evaluate the tax cost associated with inducing collaboration against the incremental benefit of the innovative opportunity. Therefore, I first solve for HQ's optimal expected payoff if it chooses to pursue the innovative opportunity. This problem can be formulated with a linear program adjusting for each model's assumptions. After solving each LP, I compare its optimal solution with the maximum payoff to HQ if it forgoes the innovative opportunity, to determine whether the innovative opportunity is worth pursuing. I state the optimal allocation for each of the model extensions.

4.2.1 Model 1

As with the base model, HQ allocates physical capital at *Time 1* and wishes to induce both subsidiaries to contribute intellectually to the prototype at *Time 2* and again to invest in the innovative project at *Time 4*, then the allocation must be incentive-compatible these two choices. This problem can be formulated with the following linear program (LP-1), where HQ's capital allocation maximizes the total expected payoff subject to the incentive-compatible constraints of both subsidiaries. Let (λ^H, λ^L) denote the amount of capital that HQ allocates to the high-tax and low-tax subsidiary, respectively.

(LP-1)

$$\max_{\lambda^H,\lambda^L} \; p(\beta+\gamma)\big((1-\tau-h)\lambda^H+(1-\tau)\lambda^L\big)+(1-p)\beta\big((1-\tau-h)\lambda^H+(1-\tau)\lambda^L\big)$$

subject to

$$p(1-\omega)(\beta+\gamma)\big((1-\tau-h)\lambda^H+(1-\tau)\lambda^L\big)+(1-p)\beta(1-\tau-h)\lambda^H \geq \beta(1-\tau-h)\lambda^H \;\; (1)$$

$$p\omega(\beta+\gamma)\big((1-\tau-h)\lambda^H+(1-\tau)\lambda^L\big)+(1-p)\beta(1-\tau)\lambda^L \geq \beta(1-\tau)\lambda^L \;\; (2)$$

$$(1-\omega)(\beta+\gamma)\big((1-\tau-h)\lambda^H+(1-\tau)\lambda^L\big) \geq \beta(1-\tau-h)\lambda^H \;\; (3)$$

$$\omega(\beta+\gamma)\big((1-\tau-h)\lambda^H+(1-\tau)\lambda^L\big) \geq \beta(1-\tau)\lambda^L \;\; (4)$$

$$\lambda^H+\lambda^L=\lambda \; (5)$$

$$\lambda^H,\lambda^L \geq 0 \; (6)$$

Inequalities (1) and (2) are the *Time 2* incentive compatibility constraints for subsidiary H and L, respectively. These inequalities ensure that, for both subsidiaries, the expected payoff for contributing intellectually during the prototype stage exceeds that for not contributing. If both subsidiaries contribute intellectually, the prototype has a probability p to succeed and a probability $1-p$ to fail. However, if either subsidiary withholds its contribution, then the prototype will surely fail. Knowing this, HQ must incentivize both subsidiaries to contribute intellectually. Therefore, if a subsidiary contributes, it expects to receive its share from the innovative project with probability p, and to earn the baseline return from its traditional project with probability $1-p$. On the other hand, if a subsidiary decides not to contribute, then the prototype surely fails, and the subsidiary earns its payoff from the traditional project.

Inequalities (3) and (4) are the *Time 4* incentive compatibility constraints for subsidiary H and L, respectively. Once the prototype succeeds, the subsidiaries have the choice to invest the capital allocated from HQ into either the innovative or the traditional project. Therefore, HQ's allocation must incentivize both subsidiaries to choose innovation with their investment choices. Inequalities (3) and (4) ensure that once the subsidiaries observe prototype success, its payoff for investing in the innovative project exceeds that for investing in the traditional project.

Inequalities (5) and (6) ensure that HQ allocates all the capital between the two subsidiaries and can be viewed as the standard budget constraints. Note that these constraints must be binding. As discussed in Chapter 3, the total amount of capital available is what HQ decides to set aside for this specific project, and unallocated capital does not earn any return. What matters is not the total amount of capital to be allocated, but rather the split between the two subsidiaries.

Proposition 1.1 the solution to LP-1 is the following:

3. If $\gamma \geq \frac{1-\omega}{\omega}\beta$, $(\lambda^H, \lambda^L) = (0, \lambda)$
4. If $\gamma \leq \frac{1-\omega}{\omega}\beta$, $(\lambda^H, \lambda^L) = (\lambda - s_L, s_L)$, where

$$s_L = \frac{\omega(\beta+\gamma)(1-\tau-h)}{\beta(1-\tau)-\omega(\beta+\gamma)h}\lambda$$

The interpretation of this result is like that documented in the previous chapter. The first case represents the first-best scenario where the tax savings are maximized and both subsidiaries choose to undertake the innovative opportunity. This occurs when the innovative project offers an incremental return that is so high that both subsidiaries naturally prefer it over their traditional projects. However, when the incremental return is not so high, the first-best solution is not available, and HQ must induce both subsidiaries to collaborate on the innovative project with its capital allocation. HQ does so at the lowest tax cost possible, and the second case presents the optimal allocation that achieves this. Note that this optimal allocation takes the same value as the base case. This is because the allocation that incentivizes the *Time 4* investment decision also incentivizes the *Time 2* intellectual contribution decision.

Proposition 2.1 Optimal allocation of Model 1

If $\gamma < \frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta$, inducing collaboration is not worthwhile, and $(\lambda^{H*}, \lambda^{L*}) = (0, \lambda)$.

If $\gamma > \frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta$, inducing collaboration is worthwhile, and the optimal allocation is:

1. $(\lambda^{H*}, \lambda^{L*}) = (0, \lambda)$ if $\gamma > \frac{1-\omega}{\omega}\beta$.
2. $(\lambda^{H*}, \lambda^{L*}) = (\lambda - s_L, s_L)$ if $\frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta < \gamma < \frac{1-\omega}{\omega}\beta$.

After HQ computes the maximum expected payoff for pursuing the innovative opportunity, it then compares it with the maximum expected payoff for not pursing this opportunity. When the first-best solution is not available, coordinating collaboration on the innovative project has a tax cost, so HQ trades off the benefit of this opportunity against the tax costs associated with coordination. If the benefit does not outweigh the cost, HQ optimally forgoes the innovative opportunity and focuses only on the tax-planning objective. This occurs when the innovative opportunity's incremental profitability γ is not high enough, $\gamma < \frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta$. On the other hand, if the benefit outweighs the tax cost, HQ induces collaboration on the innovative project at the lowest tax cost possible with an optimal allocation as stated in Proposition 1.1.

I make two observations about the result. First, as p decreases, the bound to which inducing collaboration is worthwhile increases. This is because a lower probability of success reduces the expected benefit of the innovative project, requiring a higher threshold of profitability γ to compensate for the loss in expected benefit because of the lower probability of success. Second, when p equals one, the decision to contribute intellectually guarantees the success of the prototype, and the result is the same as the base model. From the subsidiary's perspective, not contributing earns a profit from the traditional project, while contributing has a chance of earning a different payoff from the innovative project. Clearly, taking the bet is worthwhile if and only if its payoff from the innovative project is higher. One may rearrange constraints (1) and (2) and observe that that they are equivalent to constraints (3) and (4).

4.2.2 Model 2

This model extension relaxes the assumption about the prototype outcome and allows the outcome to be observable and verifiable by HQ. Consequently, HQ could write a contract that specifies the amount of capital to be allocated to each subsidiary depending on the prototype outcome at *Time 3*. HQ writes a contract at *Time 1* for a set of allocation that will occur at *Time 3*. Let $(\lambda_s^H, \lambda_s^L)$ be the amount of capital that HQ specifies to allocate for a successful prototype, and $\left(\lambda_f^H, \lambda_f^L\right)$ be the amount of capital that HQ specifies to allocate if the prototype fails. This new problem can be formulated with the following linear program (LP-2)

$$\max_{\lambda_s^H,\lambda_s^L,\lambda_f^H,\lambda_f^L} p(\beta+\gamma)\big((1-\tau-h)\lambda_s^H+(1-\tau)\lambda_s^L\big)+(1-p)\beta\left((1-\tau-h)\lambda_f^H+(1-\tau)\lambda_f^L\right)$$

Subject to.

$$p(1-\omega)(\beta+\gamma)\big((1-\tau-h)\lambda_s^H+(1-\tau)\lambda_s^L\big)+(1-p)\beta(1-\tau-h)\lambda_f^H$$
$$\geq \beta(1-\tau-h)\lambda_f^H \quad (1)$$

$$p\omega(\beta+\gamma)\big((1-\tau-h)\lambda_s^H+(1-\tau)\lambda_s^L\big)+(1-p)\beta(1-\tau)\lambda_f^L \geq \beta(1-\tau)\lambda_f^L \quad (2)$$

$$(1-\omega)(\beta+\gamma)\big((1-\tau-h)\lambda_s^H+(1-\tau)\lambda_s^L\big)\geq \beta(1-\tau-h)\lambda_s^H \quad (3)$$

$$\omega(\beta+\gamma)\big((1-\tau-h)\lambda_s^H+(1-\tau)\lambda_s^L\big)\geq\beta(1-\tau)\lambda_s^L \;(4)$$

$$\lambda_s^H+\lambda_s^L=\lambda \;(5)$$

$$\lambda_f^H+\lambda_f^L=\lambda \;(6)$$

$$\lambda_s^H,\lambda_s^L,\lambda_f^H,\lambda_f^L\geq 0 \;(7)$$

Again, inequalities (1) and (2) are the incentive compatibility constraints for the *Time 2* intellectual contribution. However, because the allocation could differ depending on the prototype outcome, the payoff under prototype success is calculated by using λ_s^H and λ_s^L, and the payoff under prototype failure is calculated by using λ_f^H and λ_f^L.

Inequalities (3) and (4) are the *Time 4* incentive compatibility constraints for the two subsidiaries, H and L, respectively. Note that if the prototype fails at *Time 3*, the innovative opportunity is gone, and the only project that a subsidiary can invest in is the traditional one. In that case, there is no more decision to be made regarding the investment, so the game ends at *Time 3*. On the other hand, if the prototype succeeds at *Time 3*, then each subsidiary has a choice between the innovative and the traditional project to invest the capital it receives. As a result, the allocation that HQ specifies must provide the appropriate incentive for both subsidiaries to invest in the innovative project at *Time 4*. However, for the reasons stated above, the *Time 4* incentive constraint is only relevant if the prototype succeeds at *Time 3*. Therefore, the payoffs used in the inequalities related to the *Time 4* investment are computed with reference only to λ_s^H and λ_s^L, the capital allocation under the prototype success case.

Proposition 1.2. The optimal allocation $(\lambda_s^{H*},\lambda_s^{L*},\lambda_f^{H*},\lambda_f^{L*})$ to LP-2 can be described as:

1. If $\gamma\geq\frac{1-\omega}{\omega}\beta$,

$$(\lambda_s^{H*},\lambda_s^{L*},\lambda_f^{H*},\lambda_f^{L*})=(0,\lambda,0,\lambda).$$

2. If $\gamma < \frac{1-\omega}{\omega}\beta$,

$$\left(\lambda_s^{H*}, \lambda_s^{L*}, \lambda_f^{H*}, \lambda_f^{L*}\right) = (\lambda - s_L, s_L, \lambda - s_L, s_L)$$

where

$$s_L = \frac{\omega(\beta+\gamma)(1-\tau-h)}{\beta(1-\tau) - \omega(\beta+\gamma)h}\lambda$$

An important observation here is that unlike Model 1, Model 2 allows the allocation to differ across the two prototype outcomes. However, at the optimal solution, the allocations are the same across the two outcomes; that is $\lambda_s^{L*} = \lambda_f^{L*}$ and $\lambda_s^{H*} = \lambda_f^{H*}$. Furthermore, this optimal allocation coincides with that of Model 1. Through the option to allocate differently across prototype outcomes, HQ can seemingly incentivize the *Time 2* intellectual contribution at a lower cost. However, this benefit cannot be unlocked because the *Time 4* incentive constraints still restrict λ_s^L from becoming larger. As we shall see in Model 4, when the allocation is free from the *Time 4* incentive problem regarding each subsidiary's investment, the benefit of contracting on the prototype outcome can be realized.

Proposition 2.2 The optimal allocation under Model 2 is the following.

If $\gamma < \frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta$, inducing collaboration is not worthwhile, and $(\lambda^{H*}, \lambda^{L*}) = (0, \lambda)$.

If $\frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta < \gamma$, the optimal allocation $(\lambda_s^{H*}, \lambda_s^{L*}, \lambda_f^{H*}, \lambda_f^{L*})$ is

1. $(\lambda_s^{H*}, \lambda_s^{L*}, \lambda_f^{H*}, \lambda_f^{L*}) = (0, \lambda, 0, \lambda)$ if $\gamma > \frac{1-\omega}{\omega}\beta$.
2. $(\lambda_s^{H*}, \lambda_s^{L*}, \lambda_f^{H*}, \lambda_f^{L*}) = (\lambda - s_L, s_L, \lambda - s_L, s_L)$ if $\frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta < \gamma < \frac{1-\omega}{\omega}\beta$.

Again, when the benefit of inducing collaboration on the innovative project is not high enough, HQ optimally forgoes collaboration and focuses only on the tax-planning objective. In this case, the capital allocation needs not refer to the prototype outcome because HQ already forgoes the innovative opportunity. The second case corresponds to when the benefit is high enough that collaboration is worthwhile inducing but not high enough that it incurs no cost. In this case, HQ allocates the maximum amount of capital to the low-tax subsidiary while maintaining its preference for the innovative project. Under this case, the optimal allocation is the solution to the LP-2, as discussed in Proposition 1.2.

4.2.3 Model 3

In this extension, Model 3 relaxes the budget constraint so that that HQ needs not allocate all the capital available for the project. The revised linear program is LP-3, and Proposition 1.3 states the solution to this LP.

(LP-3)

$$\max_{\lambda_s^H,\lambda_s^L,\lambda_f^H,\lambda_f^L} p(\beta+\gamma)\big((1-\tau-h)\lambda_s^H+(1-\tau)\lambda_s^L\big)+(1-p)\beta\left((1-\tau-h)\lambda_f^H+(1-\tau)\lambda_f^L\right)$$

subject to

$$p(1-\omega)(\beta+\gamma)\big((1-\tau-h)\lambda_s^H+(1-\tau)\lambda_s^L\big)+(1-p)\beta(1-\tau-h)\lambda_f^H$$

$$\geq \beta(1-\tau-h)\lambda_f^H \ \ (1)$$

$$p\omega(\beta+\gamma)\big((1-\tau-h)\lambda_s^H+(1-\tau)\lambda_s^L\big)+(1-p)\beta(1-\tau)\lambda_f^L \geq \beta(1-\tau)\lambda_f^L \ \ (2)$$

$$(1-\omega)(\beta+\gamma)\big((1-\tau-h)\lambda_s^H+(1-\tau)\lambda_s^L\big)\geq \beta(1-\tau-h)\lambda_s^H \ \ (3)$$

$$\omega(\beta+\gamma)\big((1-\tau-h)\lambda_s^H+(1-\tau)\lambda_s^L\big)\geq \beta(1-\tau)\lambda_s^L \ \ (4)$$

$$\lambda_s^H+\lambda_s^L\leq\lambda \ (5)$$

$$\lambda_f^H+\lambda_f^L\leq\lambda \ (6)$$

$$\lambda_s^H,\lambda_s^L,\lambda_f^H,\lambda_f^L\geq 0 \ (7)$$

Proposition 1.3. The optimal allocation $(\lambda_s^{H*},\lambda_s^{L*},\lambda_f^{H*},\lambda_f^{L*})$ to LP-3 can be described as:

1. If $\gamma\geq\frac{1-\omega}{\omega}\beta$,

$$(\lambda_s^{H*},\lambda_s^{L*},\lambda_f^{H*},\lambda_f^{L*})=(0,\lambda,0,\lambda).$$

2. If $\gamma < \frac{1-\omega}{\omega}\beta$,

$$\left(\lambda_s^{H*}, \lambda_s^{L*}, \lambda_f^{H*}, \lambda_f^{L*}\right) = (\lambda - s_L, s_L, \lambda - s_L, s_L)$$

where

$$s_L = \frac{\omega(\beta+\gamma)(1-\tau-h)}{\beta(1-\tau)-\omega(\beta+\gamma)h}\lambda$$

Relaxing the budget constraints results in the same optimal solution as before, as one can see that these constraints are binding in the new LP. Because any unallocated capital does not earn any return, it is in HQ's interest to allocate all the capital to a productive use. Furthermore, allocating all the capital does not conflict with either subsidiary's incentive. One can observe that although the constraints related to the low-tax subsidiary are binding, the constraints for the high-tax subsidiary have slack. In other words, HQ can allocate the maximum amount of capital allowed by constraints (2) and (4) to the low-tax subsidiary and the remainder to the high-tax subsidiary. Because the solution to LP-3 is the same as the solution to LP-2, and the maximum payoff for not inducing collaboration is the same between the two models, the optimal allocation result for Model 3 is the same as that for Model 2. One may refer to Proposition 2.2 for this result that I do not restate here.

4.2.4 Model 4

Finally, Model 4 further relaxes the assumption on the *Time 4* investment decision and allows HQ to contract upon the investment outcome. HQ could specify a different allocation if the prototype succeeds but a subsidiary does not invest in the innovative project. Let $(\lambda_{s,I}^H, \lambda_{s,I}^L)$ be the amount of capital that HQ specifies to allocate to each subsidiary if the prototype succeeds and the subsidiary invests in innovation. Similarly, let $(\lambda_{s,T}^H, \lambda_{s,T}^L)$ be the amount of capital that HQ specifies to allocate to each subsidiary if the prototype succeeds but the subsidiary invests in traditional project. Finally, as with the previous model, let $(\lambda_f^H, \lambda_f^L)$ be the amount of capital that

HQ specifies to allocate to each subsidiary if the prototype fails. The only investment option is the traditional project when the prototype fails, so whether a subsidiary invests in innovation or not is irrelevant for this set of allocation. The problem can be formulated with the following linear program.

(LP-4)

$$\max_{\lambda_{s,I}^H,\lambda_{s,I}^L,\lambda_{s,T}^H,\lambda_{s,T}^L,\lambda_f^H,\lambda_f^L} p(\beta+\gamma)\left((1-\tau-h)\lambda_{s,I}^H+(1-\tau)\lambda_{s,I}^L\right)$$

$$+(1-p)\beta\left((1-\tau-h)\lambda_f^H+(1-\tau)\lambda_f^L\right)$$

subject to

$$p(1-\omega)(\beta+\gamma)\left((1-\tau-h)\lambda_{s,I}^H+(1-\tau)\lambda_{s,I}^L\right)+(1-p)\beta(1-\tau-h)\lambda_f^H$$

$$\geq \beta(1-\tau-h)\lambda_f^H \ \ (1)$$

$$p\omega(\beta+\gamma)\left((1-\tau-h)\lambda_{s,I}^H+(1-\tau)\lambda_{s,I}^L\right)+(1-p)\beta(1-\tau)\lambda_f^L \geq \beta(1-\tau)\lambda_f^L \ \ (2)$$

$$(1-\omega)(\beta+\gamma)\left((1-\tau-h)\lambda_{s,I}^H+(1-\tau)\lambda_{s,I}^L\right) \geq \beta(1-\tau-h)\lambda_{s,T}^H \ \ (3)$$

$$\omega(\beta+\gamma)\left((1-\tau-h)\lambda_{s,I}^H+(1-\tau)\lambda_{s,I}^L\right) \geq \beta(1-\tau)\lambda_{s,T}^L \ \ (4)$$

$$\lambda_{s,I}^H+\lambda_{s,I}^L \leq \lambda \ (5)$$

$$\lambda_{s,T}^H+\lambda_{s,T}^L \leq \lambda \ (6)$$

$$\lambda_f^H+\lambda_f^L \leq \lambda \ (7)$$

$$\lambda_{s,I}^H,\lambda_{s,I}^L,\lambda_{s,T}^H,\lambda_{s,T}^L,\lambda_f^H,\lambda_f^L \geq 0 \ (8)$$

Inequalities (1) and (2) are the incentive compatibility constraints for the *Time 2* intellectual contribution and are the same as in LP-2. However, inequalities (3) and (4) now allow HQ to specify an allocation that penalizes the subsidiary that does not invest in innovation after the prototype succeeds.

Proposition 1.4.

The optimal allocation $(\lambda_{s,I}^{H*}, \lambda_{s,I}^{L*}, \lambda_{s,T}^{H*}, \lambda_{s,T}^{L*}, \lambda_f^{H*}, \lambda_f^{L*})$ to LP-4 can be described as:

1. If $\gamma \geq \frac{1-\omega}{\omega}\beta$, the optimal allocation is

$$\left(\lambda_{s,I}^{H*}, \lambda_{s,I}^{L*}, \lambda_{s,T}^{H*}, \lambda_{s,T}^{L*}, \lambda_f^{H*}, \lambda_f^{L*}\right) = \left(0, \lambda, \lambda_{s,T}^{H*}, \lambda_{s,T}^{L*}, 0, \lambda\right)$$

   where $\lambda_{s,T}^{H*}, \lambda_{s,T}^{L*}$ can take any value in the feasible region

$$\max\left\{0, \lambda - \frac{(1-\omega)(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau-h)}\right\} \leq \lambda_{s,T}^{L*} \leq \lambda$$

2. If $\gamma < \frac{1-\omega}{\omega}\beta$, the optimal allocation is

$$(\lambda_{s,I}^{H*}, \lambda_{s,I}^{L*}, \lambda_{s,T}^{H*}, \lambda_{s,T}^{L*}, \lambda_f^{H*}, \lambda_f^{L*}) = \left(0, \lambda, \lambda_{s,T}^{H*}, \lambda_{s,T}^{L*}, \lambda - \frac{\omega(\beta+\gamma)}{\beta}\lambda, \frac{\omega(\beta+\gamma)}{\beta}\lambda\right)$$

   where $\lambda_{s,T}^{H*}, \lambda_{s,T}^{L*}$ can take any value in the feasible region

$$\max\left\{0, \lambda - \frac{(1-\omega)(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau-h)}\right\} \leq \lambda_{s,T}^{L*} \leq \frac{\omega(\beta+\gamma)}{\beta}\lambda$$

As with the previous model setups, the first case corresponds to the first-best solution when the incremental return offered by innovation is so high that both subsidiaries naturally prefer it. For the second case, from HQ's perspective, the benefit of contracting on the investment outcome is that the capital allocation only needs to incentivize the *Time 2* intellectual contribution without worrying about the *Time 4* investment decisions. As a result, after the prototype succeeds, HQ is free to allocate all the capital to the low-tax subsidiary to achieve the maximum tax savings. However, the subsidiary's action regarding its intellectual contribution remains hidden, and the *Time 2* incentive problem remains. As a result, HQ cannot achieve the first-best outcome and must allocate a smaller amount of capital to the low-tax subsidiary if the prototype fails. In fact, if the low-tax subsidiary receives all the capital under both prototype outcomes, then it clearly has an incentive to withhold its intellectual contribution and let the prototype fail, so that it can invest in the traditional project and keeps all the profit.

Unlike the previous models, the optimal allocation for Model 4 does not depend on the extent of the tax-rate differential between the two subsidiaries. As shown in Case 2, the optimal allocation makes no reference to parameter h. The optimal allocation associated with the success outcome does not refer to h, because it is simply the tax-minimizing allocation. With the *Time 4* investment being contractable, once HQ observes prototype success, it can allocate all the capital to the low-tax subsidiary without worrying about its investment incentive. To derive the optimal allocation associated with failure, the *Time 2* incentive constraint requires that the expected payoff under failure does not exceed that under success. At the optimal solution, the allocation under failure equates the expected payoff associated with the two outcomes, to the low-tax subsidiary. Because the allocation for success does not refer to h, the allocation for failure does not refer to h either.

I make two other observations about this result. First, the upfront contract allows HQ to assign different allocations for different prototype outcomes. After relaxing the *Time 4* investment constraint, the optimal allocation is indeed different between the two prototype outcomes. Compared with Model 2, where the benefit of having different allocations is limited by the *Time 2* constraints, the allocation in Model 4 is no longer limited by the *Time 4* constraints. Second, as discussed earlier, the option to allocate differently across prototype outcomes should confer HQ the ability to incentivize the *Time 2* intellectual contribution at a lower tax cost. Indeed, if the prototype succeeds, HQ can garner all the tax savings simply by allocating all the capital to the low-tax subsidiary. Furthermore, if the prototype fails, the optimal allocation to the low-tax subsidiary is higher in Model 4 than in Model 2, and thus induces the *Time 2* contribution at a lower tax cost.

Proposition 2.4 The optimal allocation under Model 4 is the following.

If $\gamma < \frac{(1-p)(1-\omega)h}{p(1-\tau-\omega h)+\omega h}\beta$, inducing collaboration is not worthwhile, and $(\lambda^{H*}, \lambda^{L*}) = (0, \lambda)$.

If $\frac{(1-p)(1-\omega)h}{p(1-\tau-\omega h)+\omega h}\beta < \gamma$, the optimal allocation $(\lambda_s^{H*}, \lambda_s^{L*}, \lambda_f^{H*}, \lambda_f^{L*})$ is

1. If $\gamma > \frac{1-\omega}{\omega}\beta$,

$$\left(\lambda_{s,I}^{H*}, \lambda_{s,I}^{L*}, \lambda_{s,T}^{H*}, \lambda_{s,T}^{L*}, \lambda_f^{H*}, \lambda_f^{L*}\right) = \left(0, \lambda, \lambda_{s,T}^{H*}, \lambda_{s,T}^{L*}, 0, \lambda\right)$$

   where

$$\max\left\{0, \lambda - \frac{(1-\omega)(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau-h)}\right\} \leq \lambda_{s,T}^{L*} \leq \lambda$$

2. If $\frac{(1-p)(1-\omega)h}{p(1-\tau-\omega h)+\omega h}\beta < \gamma < \frac{1-\omega}{\omega}\beta$,

$$\left(\lambda_{s,I}^{H*}, \lambda_{s,I}^{L*}, \lambda_{s,T}^{H*}, \lambda_{s,T}^{L*}, \lambda_f^{H*}, \lambda_f^{L*}\right) = \left(0, \lambda, \lambda_{s,T}^{H*}, \lambda_{s,T}^{L*}, \lambda - \frac{\omega(\beta+\gamma)}{\beta}\lambda, \frac{\omega(\beta+\gamma)}{\beta}\lambda\right)$$

   where

$$\max\left\{0, \lambda - \frac{(1-\omega)(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau-h)}\right\} \leq \lambda_{s,T}^{L*} \leq \frac{\omega(\beta+\gamma)}{\beta}\lambda$$

HQ compares the incremental return with the tax costs associated with inducing collaboration on the innovative project. By contracting the amount of capital allocation on the outcome of the prototype, HQ can induce collaboration and incurs no tax cost if the prototype succeeds. However, HQ still incurs a tax cost to induce collaboration if the prototype fails. HQ compares the expected tax costs to the expected benefits of the innovative project. When γ is high enough, HQ induces collaboration at the lowest tax cost, and the optimal allocation is the solution to the

LP-4, as stated in Proposition 1.4. On the other hand, when γ is not high enough, HQ forgoes the innovative project and allocates all the capital to the low-tax subsidiary and minimizes taxes.

4.3 Model Comparison and Credible Commitment

In this section, I compare and discuss the results obtained for the different model extensions. I discuss the implications for relaxing each assumption and the advantages and disadvantages of contracting capital allocation on the prototype outcome.

4.3.1 Model comparisons

The result for each model specification has two important aspects. First is the threshold on of the incremental profitability that is required from the innovative opportunity, above which inducing collaboration becomes worthwhile; hereinafter, the inducing threshold. The lower the threshold, the smaller the tax cost associated with inducing collaboration is, because the threshold represents the required rate of return that offsets the tax costs associated with inducing collaboration. Second is the optimal allocation amount that induces collaboration. When the first-best solution is not available, inducing collaboration cannot coincide with tax minimization. However, among all the collaboration-inducing allocations, the higher the amount allocated to the low-tax subsidiary is, the higher the expected payoff associated with inducing collaboration is. Therefore, comparing the optimal allocation amounts across models also compares the expected payoff associated with inducing collaboration across the models. Table 3 summarizes the inducing threshold and the optimal allocation for each model.

Table 3. Model comparison

Model Specification	Inducing Threshold (γ_{induce})	Optimal allocation to induce collaboration
Base Model	$\frac{(1-\omega)h}{(1-\tau-h)+\omega h}\beta$	$(\lambda^{H*}, \lambda^{L*}) = (\lambda - s_L, s_L)$
Model 1	$\frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta$	$(\lambda^{H*}, \lambda^{L*}) = (\lambda - s_L, s_L)$

Model 2	$\frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta$	$(\lambda_s^{H*}, \lambda_s^{L*}, \lambda_f^{H*}, \lambda_f^{L*}) = (\lambda - s_L, s_L, \lambda - s_L, s_L)$
Model 3	$\frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta$	$(\lambda_s^{H*}, \lambda_s^{L*}, \lambda_f^{H*}, \lambda_f^{L*}) = (\lambda - s_L, s_L, \lambda - s_L, s_L)$
Model 4	$\frac{(1-p)(1-\omega)h}{p(1-\tau-\omega h)+\omega h}\beta$	$(\lambda_{s,I}^{H*}, \lambda_{s,I}^{L*}, \lambda_f^{H*}, \lambda_f^{L*}) = (0, \lambda, \lambda - \frac{\omega(\beta+\gamma)}{\beta}\lambda, \frac{\omega(\beta+\gamma)}{\beta}\lambda)$

In terms of the optimal allocation amount, Model 1 has the same optimal allocation as the base model. As explained earlier, from the subsidiary's perspective, taking a bet in the innovative project is worthwhile only if the innovative project offers a higher payoff than the subsidiary's traditional process. Therefore, an incentive-compatible allocation from the base model would also be incentive-compatible in Model 1. Introducing a risk of failure of the innovative project does not change the subsidiary's incentive, so the optimal allocation from the base model still provides the relevant incentives for the *Time 2* intellectual contribution and the *Time 4* investment decisions in Model 1. This is because the base model's optimal solution allocates the maximum amount of capital allowed by the low-tax subsidiary's incentive constraints.

Comparing the optimal allocation between Model 2 and Model 3, one can see that contracting the amount of capital on the prototype outcome does not improve the allocation outcome. HQ can allocate still only up to s_L the low-tax subsidiary to maintain its incentive compatibility constraints. Furthermore, HQ is restricted by this upper bound both when it specifies for the success outcome and when it specifies for the failure outcome. Therefore, relaxing the assumption on the contractility of the prototype outcome alone does not achieve a higher overall payoff. This is because the allocation must still incentivize both subsidiaries to invest in innovation after the prototype has succeeded. This incentive constraint limits HQ's ability to allocate too much capital to the low-tax subsidiary.

Indeed, when the *Time 4* investment decision becomes contractable, as in Model 4, contracting the allocation on the prototype outcome becomes beneficial. By imposing a large enough penalty to the subsidiary that chooses not to invest in innovation even after the prototype succeeds, HQ can enforce the subsidiaries to make the right investment choice, so that the capital allocation is free from the incentive problem at Time 4. As a result, HQ could specify an allocation of all the capital to the low-tax subsidiary if the prototype succeeds, thereby minimizing taxes while coordinating collaboration. However, HQ cannot specify the same tax-minimizing allocation for the failure case. To incentivize both subsidiaries to contribute intellectually at *Time 2*, the allocation must distinguish between the success case and the failure case. The allocation must ensure that each subsidiary's payoff associated with a success must be greater than its payoff associated with a failure, otherwise a subsidiary is better off not contributing intellectually and simply letting the innovation fail. Finally, one can check that the limit on $\lambda_f^{L*}$is greater than s_L, the limit obtained in the other model setups. Taken together, the expected payoff for inducing collaboration is the highest in Model 4.

Proposition 3 The comparison of the inducing threshold across models is the following:

1. $\gamma_{induce-base} < \gamma_{induce-1} = \gamma_{induce-2} = \gamma_{induce-3}$
2. $\gamma_{induce-4} < \gamma_{induce-1} = \gamma_{induce-2} = \gamma_{induce-3}$
3. The comparison between $\gamma_{induce-4}$ and $\gamma_{induce-base}$ depends on p, and in particular,
    a. if $p > \frac{1-\tau-h}{2-2\tau-h}$, $\gamma_{induce-4} < \gamma_{induce-base}$, and
    b. if $p < \frac{1-\tau-h}{2-2\tau-h}$, $\gamma_{induce-base} < \gamma_{induce-4}$.

Where $\gamma_{induce-base}$ is the inducing threshold for the base model, and $\gamma_{induce-i}$ is the inducing threshold for Model $i, i \in \{1,2,3,4\}$.

Proposition 3 provides the statement of the comparison of the inducing threshold across the different models. The first comparison shows that the inducing threshold of Model 1 is higher than that of the base model. This higher required rate of return is to compensate for the lower expected benefit of inducing an innovative collaboration due to a probability of failure. Furthermore, the inducing thresholds for Models 1, 2, and 3 are the same. This is because the tax cost associated with inducing collaboration is the same across the three models, as discussed above. The second comparison shows that Model 4 has a lower inducing threshold than Models 1, 2, and 3. This is because the allocation in Model 4 is free from the *Time 4* incentive problem, so the optimal allocation achieves a higher expected payoff associated with inducing collaboration. The higher payoff in turn reduces the threshold on its required rate of return to offset the tax costs associated with inducing collaboration.

The comparison between Model 4 and the base model depends on the probability of success. On the one hand, compared with the base model, the innovative project in Model 4 faces a risk of failure. The prospect of earning a lower return reduces the expected payoff associated with inducing collaboration in Model 4 that in turn increases the required return on the innovative project for it to be worthwhile. On the other hand, Model 4 achieves a higher payoff when the prototype succeeds by attaining the full the tax savings. This should reduce the required return on the innovative project for it to be worthwhile. The net of the two opposite effects depends on the probability distribution between the two outcomes. When the probability of success is high, the higher payoff obtained with a success outweighs the lower payoff associated with a failure, resulting in a net positive effect and a lower inducing threshold. When the probability of a success is low, the net effect is negative, and the inducing threshold is higher.

4.3.2 Advantages and disadvantages of the upfront contract

Contracting the capital allocation on the prototype outcome depends on HQ's ability to credibly commit to allocate capital according to the contract, even after observing the prototype outcome. However, if the prototype has already failed, HQ clearly has an incentive to then allocate more to the low-tax subsidiary for tax reasons. At this point, the innovative opportunity is gone, and the effort and action from the subsidiaries are sunk. Furthermore, HQ still has full control over the capital, and neither subsidiary can enforce the original contract. Therefore, nothing prevents HQ from allocating a higher amount of capital to the low-tax subsidiary than specified in the original contract. The low-tax subsidiary certainly welcomes such an arrangement.

If the contract is subject to a credibility threat, and that the subsidiaries perceive that HQ cannot credibly commit to the original contract, then let (c_f^H, c_f^L) be the amount of capital that the subsidiaries perceive HQ would allocate after observing the prototype failure. To distinguish from the decision variables to HQ, note that these amounts are fixed constants that are perceived by the subsidiaries. With the setup of Model 2, this problem can be formulated with the following linear program (LP-2-C).

$$\max_{\lambda_s^H, \lambda_s^L} p(\beta+\gamma)\big((1-\tau-h)\lambda_s^H + (1-\tau)\lambda_s^L\big) + (1-p)\beta\left((1-\tau-h)c_f^H + (1-\tau)c_f^L\right)$$

subject to

$$p(1-\omega)(\beta+\gamma)\big((1-\tau-h)\lambda_s^H + (1-\tau)\lambda_s^L\big) + (1-p)\beta(1-\tau-h)c_f^H$$
$$\geq \beta(1-\tau-h)c_f^H \quad (1)$$

$$p\omega(\beta+\gamma)\big((1-\tau-h)\lambda_s^H + (1-\tau)\lambda_s^L\big) + (1-p)\beta(1-\tau)c_f^L \geq \beta(1-\tau)c_f^L \quad (2)$$

$$(1-\omega)(\beta+\gamma)\big((1-\tau-h)\lambda_s^H + (1-\tau)\lambda_s^L\big) \geq \beta(1-\tau-h)\lambda_s^H \quad (3)$$

$$\omega(\beta+\gamma)\big((1-\tau-h)\lambda_s^H + (1-\tau)\lambda_s^L\big) \geq \beta(1-\tau)\lambda_s^L \quad (4)$$

$$\lambda_s^H + \lambda_s^L = \lambda \ (5)$$

$$\lambda_s^H, \lambda_s^L \geq 0 \ (6)$$

Proposition 4.1 If $c_f^L > s_L$ and $\gamma < \frac{1-\omega}{\omega}\beta$, then (LP-2-C) is infeasible.

Next, I examine the effect of the credibility threat with the setup of Model 4. The problem can be formulated with the following linear program (LP-4-C).

$$\max_{\lambda_{s,I}^H, \lambda_{s,I}^L, \lambda_{s,T}^H, \lambda_{s,T}^L} p(\beta + \gamma)\left((1 - \tau - h)\lambda_{s,I}^H + (1 - \tau)\lambda_{s,I}^L\right)$$

$$+ (1 - p)\beta\left((1 - \tau - h)c_f^H + (1 - \tau)c_f^L)\right)$$

subject to

$$p(1 - \omega)(\beta + \gamma)\left((1 - \tau - h)\lambda_{s,I}^H + (1 - \tau)\lambda_{s,I}^L\right) + (1 - p)\beta(1 - \tau - h)c_f^H$$

$$\geq \beta(1 - \tau - h)c_f^L \ \ (1)$$

$$p\omega(\beta + \gamma)\left((1 - \tau - h)\lambda_{s,I}^H + (1 - \tau)\lambda_{s,I}^L\right) + (1 - p)\beta(1 - \tau)c_f^L) \ \geq \beta(1 - \tau)c_f^L \ \ (2)$$

$$(1 - \omega)(\beta + \gamma)\left((1 - \tau - h)\lambda_{s,I}^H + (1 - \tau)\lambda_{s,I}^L\right) \geq \beta(1 - \tau - h)\lambda_{s,T}^H \ \ (3)$$

$$\omega(\beta + \gamma)\left((1 - \tau - h)\lambda_{s,I}^H + (1 - \tau)\lambda_{s,I}^L\right) \geq \beta(1 - \tau)\lambda_{s,T}^L \ \ (4)$$

$$\lambda_{s,I}^H + \lambda_{s,I}^L \leq \lambda \ (5)$$

$$\lambda_{s,T}^H + \lambda_{s,T}^L \leq \lambda \ (5)$$

$$\lambda_{s,I}^H, \lambda_{s,I}^L, \lambda_{s,T}^H, \lambda_{s,T}^L \geq 0 \ (6)$$

Proposition 4.2 If $c_f^L > \frac{\omega(\beta+\gamma)}{\beta}\lambda$ and $\gamma < \frac{1-\omega}{\omega}\beta$, then (LP-4-C) is infeasible.

The above two propositions describe what happens if HQ cannot credibly commit to the original contract. Knowing this, the low-tax subsidiary has a reason to perceive that upon observing a failed prototype, HQ would allocate to it an amount that is higher than the original. In this case, it is impossible for HQ to specify an allocation λ_s^H and λ_s^L that provides both the

Time 2 and the *Time 4* incentives. This is because the allocation that incentivizes an intellectual contribution at *Time 2* must ensure that the payoff associated with a success exceeds that with a failure. If the low-tax subsidiary now perceives a higher amount of allocation and thus a higher payoff under the failure case, to maintain the *Time 2* incentive, the allocation must also increase under the success case. However, the allocation under the success case is already at the maximum allowed by the *Time 4* investment incentive under Model 2 and the maximum allowed by the budget constraint under Model 4.

Comparing contracting versus not contracting on the prototype outcome when the investment decision is not contractable (i.e., Model 1 versus Model 2), one can see that the total expected payoffs are the same. However, not contracting on the prototype outcome (Model 1) is not subject to the credibility threat. HQ commits to an allocation through giving up physical capital upfront. Comparing contracting versus not contracting on the prototype outcome when the investment decision is contractable (i.e., Model 1 versus Model 4), contracting on the prototype outcome has an advantage that results in a higher expected payoff. However, such a contract is subject to the credibility threat that could make it impossible for HQ to incentivize collaboration. In conclusion, if the *Time 4* investment decision is not contractable, then it is better to commit capital upfront. There is no additional benefit but a potential cost for contracting on the prototype outcome. On the other hand, if the *Time 4* investment decision is contractable, then it is beneficial to contract capital allocation upon the prototype outcome only if HQ can credibly commit to such an arrangement.

4.4 Summary of Model Extensions

In summary, Chapter 4 extends the base model in several ways. First, Model 1 introduces a prototype stage and incorporates a risk of failure associated with the innovative opportunity. Model 2 separates the intellectual contribution decision from the investment decision. This better reflects the difference in the type of resources that is critical to different stages of the project. Furthermore, Model 2 relaxes the assumption on the prototype outcome and allows the outcome to be contractable. The solution to Model 2 shows that relaxing this assumption alone does not improve the overall payoff because the *Time 4* constraints associated with the investment decisions are still restricting the capital allocation. Model 3 relaxes the budget constraint and obtains the same result because HQ is not a production unit itself. Finally, Model 4 further relaxes the *Time 4* investment decision and allows HQ to impose a penalty on the subsidiary that does not invest in the innovative project after the prototype has succeeded. Interestingly, the first-best solution is still not achievable, because HQ cannot know whether a subsidiary has contributed intellectually when the prototype fails.

Comparing the different models considered in Chapter 4, one can see that contracting on the prototype outcome has advantages and disadvantages. Contracting on the prototype outcome is beneficial only when HQ can enforce investment into the innovative project after the prototype has succeeded. However, contracting on the prototype outcome could face a credibility threat because it is in the interest of both HQ and the low-tax subsidiary to allocate a higher than the original amount of capital to the low-tax subsidiary after the prototype fails. In such a case, HQ cannot incentivize collaboration with any allocation. This is a disadvantage for contracting on the prototype outcome.

Chapter 5. Exogenous Tax Policy Change

Prior studies document that countries compete on their corporate income taxes to attract investment and to create jobs through increased business activities (Clausing 2009, 2016, 2007, Desai, Foley, and Hines 2003). Facing competition from low-tax jurisdictions, many high-tax countries have reduced their corporate income tax rates. The literature has not addressed how internal managerial practices of MNCs can cause them to respond differently to a tax policy change. In this thesis, I study the interaction between an MNC's coordination of lateral collaborations among its subsidiaries and its capital allocation response to a tax incentive.

A tax incentive may be general and apply to all types of income, or it may encourage a specific type of activity for a specific sector. I first consider a general corporate tax reduction that does not distinguish the type of income or the type of income-generating activity. For example, Canada's General Rate Reduction (GRR) offers a 13% rate reduction on corporate income and has been in place since 2000. The GRR lowers the typical business Canadian corporate tax rate from 45% to 32%, depending on the province. The most recent U.S. tax reform (*Tax Cuts and Jobs Act of 2017*) provides a flat corporate tax cut from 35% to 21%, plus state taxes. In the context of the model, these policies reduce the tax rates on income earned from both the innovative project and the traditional one. I examine the circumstances under which the high-tax subsidiary receives more capital allocation after the tax cut.

Suppose that a high-tax country reduces its tax rate from $\tau + h$ to $\tau + k$, where $k < h$, and this reduction applies to both the innovative and traditional projects. Applying the same technique that solves the base case, I solve for the MNC's capital allocation after the tax cut. Let the optimal allocation to the high-tax and the low-tax subsidiary be λ_k^{H*} and λ_k^{L*}, respectively, where the subscript k denotes the allocation after the tax-rate reduction that narrows the tax-rate differential from h to k.

5.1 Effect of a General Rate Reduction on an MNC's Capital Allocation – Base Model

I first consider a general rate reduction that applies to both the innovative and traditional projects. In this section, I state the result under the setup of the base model as outlined in Chapter 3. Lemma 1 states the optimal allocation after a general tax cut under the base model. Note that this is a straight application of Proposition 2 from the base model.

Lemma 1

The base model optimal allocation $(\lambda_k^{H*}, \lambda_k^{L*})$ after the general tax reduction is characterized by:

1. $(\lambda_k^{H*}, \lambda_k^{L*}) = (0, \lambda)$ if $\gamma > \frac{1-\omega}{\omega}\beta$.
2. $(\lambda_k^{H*}, \lambda_k^{L*}) = (0, \lambda)$ if $\gamma < \frac{(1-\omega)k}{1-\tau-(1-\omega)k} \cdot \beta$.
3. $(\lambda_k^{H*}, \lambda_k^{L*}) = (\lambda - s_{L,k}, s_{L,k})$ if $\frac{(1-\omega)k}{1-\tau-(1-\omega)k} \cdot \beta < \gamma < \frac{1-\omega}{\omega}\beta$, where

$$s_{L,k} = \frac{\omega(\beta+\gamma)(1-\tau-k)}{\beta(1-\tau)-\omega(\beta+\gamma)k}\lambda$$

The next proposition compares the allocation before and after the tax cut and characterizes how a capital allocation to the high-tax subsidiary changes in response to the tax cut. Contrary to conventional wisdom, the tax cut does not always result in an increase in capital allocated to the high-tax subsidiary.

Proposition 5

The base model capital allocation changes after the general tax reduction are characterized by:

1. When $\gamma > \frac{1-\omega}{\omega}\beta$ or $\gamma < \frac{(1-\omega)k}{1-\tau-(1-\omega)k} \cdot \beta$, $\lambda_k^{H*} = \lambda^{H*}$.
2. When $\frac{(1-\omega)k}{1-\tau-(1-\omega)k} \cdot \beta < \gamma < \frac{(1-\omega)h}{1-\tau-(1-\omega)h} \cdot \beta$, $\lambda_k^{H*} > \lambda^{H*}$.
3. When $\frac{(1-\omega)h}{1-\tau-(1-\omega)h} \cdot \beta < \gamma < \frac{1-\omega}{\omega}\beta$, $\lambda_k^{H*} < \lambda^{H*}$.

Proposition 5 offers three insights. First, an MNC may optimally choose not to change its behavior because of the tax policy. The first case of this proposition describes two scenarios when this happens. In the first scenario, the capital allocation is free from any incentive issues, so HQ induces collaboration on the innovative project with no tax cost, both before and after the tax cut. Here, even though the tax-minimizing strategy allocates all capital to the low-tax subsidiary, the return that the innovative project offers is high enough for the low-tax subsidiary to prefer collaborating on it. This is the first-best scenario that does not change with the tax cut.

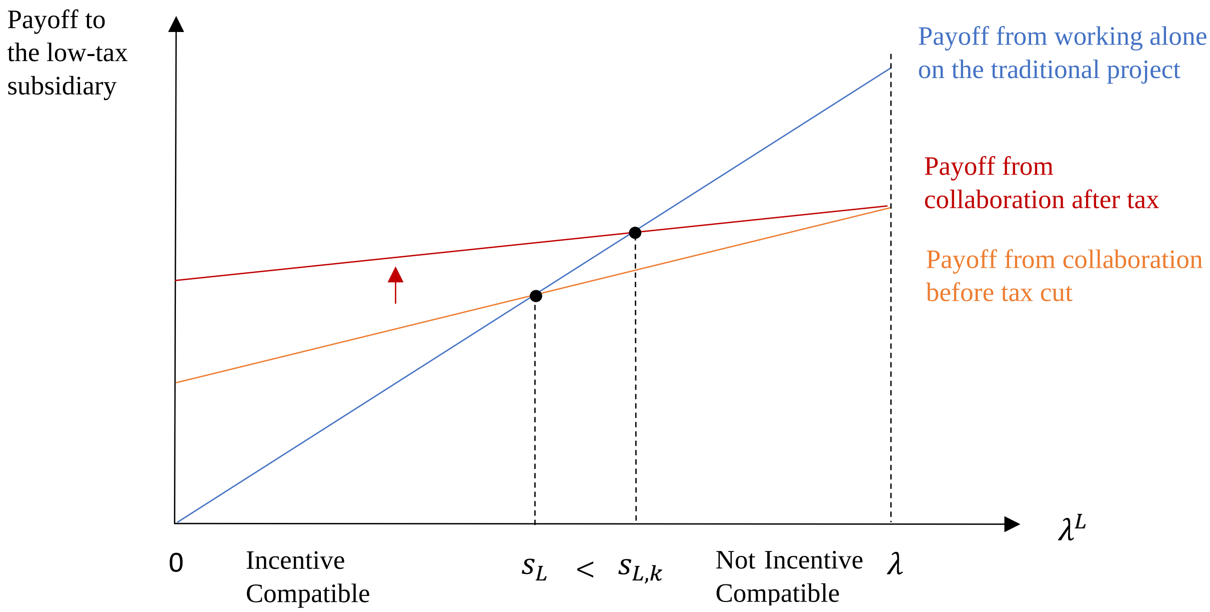
The second scenario under which the MNC does not change its capital allocation occurs when the incentive of the tax policy is not strong enough to offset the MNC's internal coordination cost. One effect of the tax cut from the high-tax country is that it reduces the tax cost associated with inducing collaboration by narrowing the tax-rate difference between the two subsidiaries. One can see that the threshold above which the innovative project is worth inducing (i.e., the inducing threshold) is lower after the tax cut. However, the innovative opportunity is still not worth pursuing if its incremental return is not high enough to generate a benefit that offsets the cost, even at a reduced amount. In this case, HQ would not induce collaboration on the innovative project, and it optimally allocates all the capital to the low-tax subsidiary, both before and after the tax cut. The second scenario in Case 1 corresponds to this situation. One would not expect a change in the capital allocation from the MNC in this case.

The second insight is as follows. Because the tax cut reduces the tax cost of inducing collaboration on the innovative project, it could be that the innovative opportunity is not worthwhile pursuing before the tax cut but becomes worthwhile with the help of the tax cut. This occurs when the incremental return on the innovative project does not meet the inducing threshold prior to the tax cut but meets the inducing threshold that has been lowered by the tax cut. The extent of the reduction of the inducing threshold increases with the extent of the tax cut. The higher the tax-rate reduction, the more tax cost it alleviates from inducing collaboration, and the more likely inducing collaboration is worthwhile. In algebraic terms, a smaller k corresponds to a lower inducing threshold.[4]

The third insight is as follows. If the innovative opportunity is worth pursuing even without the help of the tax cut, then it is surely worth pursuing after the tax cut. However, in this case, HQ optimally allocates more to the low-tax subsidiary and less to the high-tax subsidiary, contrary to conventional wisdom. This is because the tax cut offered by the high-tax country alleviates the incentive problem and reduces the coordination cost that are internal to the MNC, which turns out to be an unintentional effect of the policy. By increasing the after-tax profit that the high-tax subsidiary can bring to the collaboration and share with the low-tax subsidiary, the tax cut effectively makes collaboration more appealing to the low-tax subsidiary. As a result, the tax cut expands the set of incentive-compatible allocations, allowing HQ to induce collaboration at a lower tax cost, through allocating more capital to the low-tax subsidiary. As illustrated in Figure 4, the tax cut creates an upward shift in the low-tax subsidiary's payoff from collaboration, pushing $s_{L,k}$ to the right of s_L.

[4] In this model, I specifically consider cases when $k > 0$. I note that in the case when $k = 0$, there is no longer any tax cost associated with inducing collaboration, so collaboration is always worthwhile inducing. In algebraic terms, the inducing threshold becomes zero.

Figure 4. Changes in allocation after the tax cut



In summary, the effect of the tax cut is twofold. First, it reduces the tax cost associated with inducing collaboration, and second, it alleviates an incentive problem by making collaboration more appealing to the low-tax subsidiary. Therefore, the MNC's response to the tax cut depends on how the tax cut changes the MNC's tradeoff between tax savings and inducing collaboration. The model shows that the MNC decreases its capital allocation to the high-tax subsidiary when the innovative opportunity is worth pursuing prior to the tax cut. On the other hand, the MNC increases its capital allocation to the high-tax subsidiary when the innovative opportunity offers a return that worth inducing only with the help of the tax cut.

5.2 Specific Tax Reduction and the Patent-Box Regime – With the Base Model

Next, I consider a tax cut from the high-tax country that applies only to the innovative project. In recent years, the patent-box regime has become increasingly popular in Europe, and 13 European countries have implemented the regime as of 2020. Outside Europe, China has introduced its own patent box, while lobbying effort continues in Canada and the U.S. for similar regimes. One of the two main policy objectives is to attract innovative resources and boost innovative activities within the country that implements the regime (Alstadsæter et al. 2015, Bradley, Dauchy, and Robinson 2015, Chen et al. 2018). The other objective is to protect the tax base and retain income that might otherwise be shifted to lower-tax countries.

Studies document that patents ownership increases for a country that implements a patent-box regime following the implementation, consistent with firms responding to the tax incentive with their patent location choice, both for developed and acquired patents (Alstadsæter et al. 2015, Bradley, Dauchy, and Robinson 2015, Bradley, Ruf, and Robinson 2018, Böhm et al. 2015). However, the regime's effect on capital investment and innovative activity is inconclusive. While Chen et al. (2018) find an overall increase in fixed assets in subsidiaries located in patent-box countries after the implementation of a regime, Schwab and Todtenhaupt (2019) document that a country's innovative capital is affected by the introduction of a patent-box regime in another country. However, the literature on patent-box regimes has not considered an MNC's internal coordination cost as a factor that affects the policy's effect on an MNC's capital allocation. My study contributes to this literature by studying how an MNC's capital allocation addresses the need for subsidiaries to collaborate on an innovative opportunity.

A patent-box regime taxes income from innovation-related activities at a significantly lower rate than from other corporate income. Unlike traditional R&D tax incentives that subsidize the input cost on innovation efforts, the patent-box regime reduces the tax rate on income earned from the output of an innovation effort. As such, the tax benefit rewards only successful innovations but not those that fail. For these reasons, in the base model, the tax reduction from the high-tax country applies only to the innovative project, and in the model extensions, the tax reduction applies only if the two subsidiaries successfully develop the prototype and invest in the innovative project.

Suppose that the high-tax country reduces its tax rate $\tau + h$ to $\tau + k$, but only for income earned on innovations. The innovative opportunity qualifies for the tax reduction, but the traditional project remains taxed at $\tau + h$. Lemma 2 characterizes the optimal allocation after this specific tax reduction for the base model.

Lemma 2

The base model optimal allocation $(\lambda_k^{H*}, \lambda_k^{L*})$ after the **specific** tax reduction is characterized by:

1. $(\lambda_k^{H*}, \lambda_k^{L*}) = (0, \lambda)$ if $\gamma > \frac{1-\omega}{\omega}\beta$.
2. $(\lambda_k^{H*}, \lambda_k^{L*}) = (0, \lambda)$ if $\gamma < \frac{(1-\omega)k}{1-\tau-(1-\omega)k} \cdot \beta$.
3. $(\lambda_k^{H*}, \lambda_k^{L*}) = (\lambda - s_{L,k}, s_{L,k})$ if $\frac{(1-\omega)k}{1-\tau-(1-\omega)k} \cdot \beta < \gamma < \frac{1-\omega}{\omega}\beta$, where

$$s_{L,k} = \frac{\omega(\beta+\gamma)(1-\tau-k)}{\beta(1-\tau)-\omega(\beta+\gamma)k}\lambda$$

Note that the optimal allocation after the specific rate reduction is the same as in the case of a general rate reduction. The first case corresponds to the first-best solution when the tax-minimization objective does not conflict with the coordination objective. HQ maximizes tax savings by allocating all the capital to the low-tax subsidiary, and the two subsidiaries collaborate on the innovative project. This is true regardless of whether there is a tax cut and whether the tax cut is general or specific.

To see why the specific rate reduction as the same effect as the general one in Cases 2 and 3, let us revert to the two effects of the tax cut. The first effect reduces the tax cost associated with inducing collaboration, but this benefit is relevant only when HQ incentivizes both subsidiaries to work on the innovative project. In other words, this first effect depends solely on the high-tax subsidiary's tax rate on the innovative project, and this rate is the same between the two types of tax cut. Therefore, the first effect (i.e., the Case 2 result) is the same for both types of tax cut. The second effect alleviates the incentive problem by making collaboration more appealing to the low-tax subsidiary. Neither type of tax cut changes the low-tax subsidiary's payoff for working alone, while both types of tax cut increase the payoff for working together. This payoff is increased to the same extent because it refers only to the tax rate applicable to the innovative project, and whether there is a corresponding tax cut on traditional production is irrelevant.

I then compare the capital allocations before and after the specific rate reduction to study the MNC's capital allocation changes in response to the specific tax rate reduction. Proposition 6 states the result.

Proposition 6

The base model capital allocation changes after the **specific** tax reduction are characterized by:

1. When $\gamma > \frac{1-\omega}{\omega}\beta$ or $\gamma < \frac{(1-\omega)k}{1-\tau-(1-\omega)k} \cdot \beta$, $\lambda_k^{H*} = \lambda^{H*}$.
2. When $\frac{(1-\omega)k}{1-\tau-(1-\omega)k} \cdot \beta < \gamma < \frac{(1-\omega)h}{1-\tau-(1-\omega)h} \cdot \beta$, $\lambda_k^{H*} > \lambda^{H*}$.
3. When $\frac{(1-\omega)h}{1-\tau-(1-\omega)h} \cdot \beta < \gamma < \frac{1-\omega}{\omega}\beta$, $\lambda_k^{H*} < \lambda^{H*}$.

Because the specific tax reduction has the same effect on the optimal allocation as the general rate reduction, its effect on the changes in capital allocation is also the same as the general rate reduction. One can see that Proposition 6 is the same as Proposition 5, for the base model.

5.3 Effect of a General Rate Reduction – Model Extensions

I revisit the results of the general tax-rate reductions for the model extensions as outlined in Chapter 4. Lemma 1.1 states the optimal allocation after a general rate reduction for Model 1 in Chapter 4, where the innovative project faces a risk of failure, the prototype outcome is not contactable, so HQ allocates physical capital upfront to the subsidiaries. One can apply Proposition 2.1 with the reduced tax rate $\tau + k$ to reach this result.

Lemma 1.1

For Model 1, the optimal allocation $(\lambda_k^{H*}, \lambda_k^{L*})$ after the general tax reduction is characterized by:

1. $(\lambda_k^{H*}, \lambda_k^{L*}) = (0, \lambda)$ if $\gamma > \frac{1-\omega}{\omega}\beta$.
2. $(\lambda_k^{H*}, \lambda_k^{L*}) = (0, \lambda)$ if $\gamma < \frac{(1-\omega)k}{p(1-\tau-k)+\omega k}\beta$.
3. $(\lambda_k^{H*}, \lambda_k^{L*}) = (\lambda - s_{L,k}, s_{L,k})$ if $\frac{(1-\omega)k}{p(1-\tau-k)+\omega k}\beta < \gamma < \frac{1-\omega}{\omega}\beta$, where

$$s_{L,k} = \frac{\omega(\beta+\gamma)(1-\tau-k)}{\beta(1-\tau)-\omega(\beta+\gamma)k}\lambda$$

Next, I compare the optimal allocation before and after the general rate reduction to derive the changes in capital allocation. Proposition 5.1 states this result.

Proposition 5.1

For Model 1, the capital allocation changes after the general tax reduction are characterized by:

1. When $\gamma > \frac{1-\omega}{\omega}\beta$ or $\gamma < \frac{(1-\omega)k}{p(1-\tau-k)+\omega k}\beta$, $\lambda_k^{H*} = \lambda^{H*}$.
2. When $\frac{(1-\omega)k}{p(1-\tau-k)+\omega k}\beta < \gamma < \frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta$, $\lambda_k^{H*} > \lambda^{H*}$.
3. When $\frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta < \gamma < \frac{1-\omega}{\omega}\beta$, $\lambda_k^{H*} < \lambda^{H*}$.

As with the result obtained for the base model, the effect of the general rate reduction is twofold. The first effect reduces the tax cost associated with inducing both subsidiaries to collaborate on the innovative project. Aa a result, the innovative opportunity that does not meet the inducing threshold prior to the tax cut might meet the reduced threshold after the tax cut. HQ starts inducing collaboration only after the tax cut by allocating more capital to the high-tax subsidiary. On the other hand, the incremental return on the innovative opportunity may be so low that it does not even meet the reduced threshold after the tax cut. HQ forgoes collaboration and maximizes tax savings both before and after the tax cut, and the optimal capital allocation does not change in this case. Note that the inducing threshold after the general tax cut of Model 1 is higher than that of the base model (i.e., comparing with Proposition 5). This higher inducing threshold reflects a higher requirement on the innovative profitability posed by the possibility of innovation failure. The second effect of the tax cut makes collaboration more appealing to the low-tax subsidiary by offering a higher amount that the high-tax subsidiary can share. This effect alleviates the internal incentive problem, allowing HQ to allocate even more to the low-tax subsidiary. This occurs when the innovative opportunity warrants the coordination cost, even before the tax cut.

Model 2 relaxes the verifiability assumption of the prototype outcome, so that it becomes contractable, and HQ can design an upfront contract that specifies an allocation for each prototype outcome. Lemma 1.2 states the optimal allocation after the general rate reduction for this model specification. For this general rate reduction, one can apply Proposition 2.2 to derive this result with the reduced tax rate of $\tau + k$.

Lemma 1.2

For Model 2, the optimal allocation $(\lambda_{s,k}^{H*}, \lambda_{s,k}^{L*}, \lambda_{f,k}^{H*}, \lambda_{f,k}^{L*})$ after the general tax reduction is characterized by:

1. If $\gamma < \frac{(1-\omega)k}{p(1-\tau-k)+\omega k}\beta$, inducing collaboration is not worthwhile, and $(\lambda_k^{H*}, \lambda_k^{L*}) = (0, \lambda)$.
2. If $\frac{(1-\omega)k}{p(1-\tau-k)+\omega k}\beta < \gamma$, the optimal allocation is:
   3. $(\lambda_{s,k}^{H*}, \lambda_{s,k}^{L*}, \lambda_{f,k}^{H*}, \lambda_{f,k}^{L*}) = (0, \lambda, 0, \lambda)$ if $\gamma > \frac{1-\omega}{\omega}\beta$.
   4. $(\lambda_{s,k}^{H*}, \lambda_{s,k}^{L*}, \lambda_{f,k}^{H*}, \lambda_{f,k}^{L*}) = (\lambda - s_{L,k}, s_{L,k}, \lambda - s_{L,k}, s_{L,k})$ if $\frac{(1-\omega)k}{p(1-\tau-k)+\omega k}\beta < \gamma < \frac{1-\omega}{\omega}\beta$,

      where

$$s_{L,k} = \frac{\omega(\beta+\gamma)(1-\tau-k)}{\beta(1-\tau)-\omega(\beta+\gamma)k}\lambda$$

I then compare the optimal allocation before and after the general rate reduction to derive the changes in capital allocation. Proposition 5.2 states this result for Model 2.

Proposition 5.2

For Model 2, the capital allocation changes after the general tax reduction is characterized by:

1. When $\gamma < \frac{(1-\omega)k}{p(1-\tau-k)+\omega k}\beta$, inducing collaboration is not worthwhile, even after the general rate reduction, and in this case, $\lambda_k^{H*} = \lambda^{H*}$.
2. When $\frac{(1-\omega)k}{p(1-\tau-k)+\omega k}\beta < \gamma < \frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta$, inducing collaboration becomes worthwhile only after the general tax cut, and in this case, $\lambda_{k,s}^{H*} = \lambda_{k,f}^{H*} > \lambda^{H*}$.
3. When $\gamma > \frac{1-\omega}{\omega}\beta$, $\lambda_{k,s}^{H*} = \lambda_s^{H*}$ and $\lambda_{k,f}^{H*} = \lambda_f^{H*}$.
4. When $\frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta < \gamma < \frac{1-\omega}{\omega}\beta$, $\lambda_{k,s}^{H*} < \lambda_s^{H*}$ and $\lambda_{k,f}^{H*} < \lambda_f^{H*}$.

In the case where the innovative opportunity is not worthwhile pursuing even with the help of the tax cut, the capital allocation does not need to induce collaboration on the innovative project, so it does not need to refer to the prototype outcome, as shown in Case 1. In contrast, in the case where the tax cut prompts HQ to pursue the innovative opportunity, the allocation before the tax cut does not refer to the prototype outcome, whereas the allocation after the tax cut does. As shown in Case 2, the tax cut increases the optimal allocation to the high-tax subsidiary, under both prototype outcomes. Furthermore, the allocation happens to be the same across both outcomes, consistent with Proposition 2.2 in Chapter 4. Finally, in the case where the innovative opportunity is already worth pursuing without the tax cut, the tax cut alleviates the incentive problem and allows HQ to allocate even more to the low-tax subsidiary (and hence less to the high-tax subsidiary), for both prototype outcomes, as shown in Case 4.

Model 3 allows HQ the option of not fully allocating all the available capital, but results in the same optimal allocation as Model 2, because the budget constraints are binding even though they can have slack. As a result, the implications from the tax cut for Model 3 are the same as in Model 2.

Model 4 further relaxes the assumption about the *Time 4* investment decision so that after the prototype succeeds, HQ could assign different allocations depending on the *Time 4* investment outcome. Lemma 1.4 states the optimal allocation after the general rate reduction for this model specification. One can apply Proposition 2.4 to derive this result with the general reduced tax rate of $\tau + k$.

Lemma 1.4

For Model 4, the optimal allocation after the general tax reduction is characterized by:

1. If $\gamma < \frac{(1-p)(1-\omega)k}{p(1-\tau-\omega k)+\omega k}\beta$, inducing collaboration is not worthwhile, and $(\lambda_k^{H*}, \lambda_k^{L*}) = (0, \lambda)$.

2. If $\frac{(1-p)(1-\omega)k}{p(1-\tau-\omega k)+\omega k}\beta < \gamma$, the optimal allocation $(\lambda_{s,I,k}^{H*}, \lambda_{s,I,k}^{L*}, \lambda_{s,T,k}^{H*}, \lambda_{s,T,k}^{L*}, \lambda_{f.k}^{H*}, \lambda_{f,k}^{L*})$ is

   (a) If $\gamma > \frac{1-\omega}{\omega}\beta$,

$$\left(\lambda_{s,I,k}^{H*}, \lambda_{s,I,k}^{L*}, \lambda_{s,T,k}^{H*}, \lambda_{s,T,k}^{L*}, \lambda_{f.k}^{H*}, \lambda_{f,k}^{L*}\right) = \left(0, \lambda, \lambda_{s,T,k}^{H*}, \lambda_{s,T,k}^{L*}, 0, \lambda\right)$$

   where

$$\max\left\{0, \lambda - \frac{(1-\omega)(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau-k)}\right\} \leq \lambda_{s,T,k}^{L*} \leq \lambda$$

   (b) If $\frac{(1-p)(1-\omega)k}{p(1-\tau-\omega k)+\omega k}\beta < \gamma < \frac{1-\omega}{\omega}\beta$,

$$\left(\lambda_{s,I,k}^{H*}, \lambda_{s,I,k}^{L*}, \lambda_{s,T,k}^{H*}, \lambda_{s,T,k}^{L*}, \lambda_{f.k}^{H*}, \lambda_{f,k}^{L*}\right) = \left(0, \lambda, \lambda_{s,T,k}^{H*}, \lambda_{s,T,k}^{L*}, \lambda - \frac{\omega(\beta+\gamma)}{\beta}\lambda, \frac{\omega(\beta+\gamma)}{\beta}\lambda\right)$$

   where

$$\max\left\{0, \lambda - \frac{(1-\omega)(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau-k)}\right\} \leq \lambda_{s,T,k}^{L*} \leq \frac{\omega(\beta+\gamma)}{\beta}\lambda$$

I then compare the optimal allocation before and after the general rate reduction to derive the changes in capital allocation. Proposition 5.4 states this result for Model 4.

Proposition 5.4

For Model 4, the capital allocation changes after the general tax reduction are characterized by:

1. When $\gamma < \frac{(1-p)(1-\omega)k}{p(1-\tau-\omega k)+\omega k}\beta$, inducing collaboration is not worthwhile, even after the general tax cut, and in this case, $\lambda_k^{H*} = \lambda^{H*}$.
2. When $\frac{(1-p)(1-\omega)k}{p(1-\tau-\omega k)+\omega k}\beta < \gamma < \frac{(1-p)(1-\omega)h}{p(1-\tau-\omega h)+\omega h}\beta$, inducing collaboration is worthwhile only after the general tax cut, and in this case, $\lambda_{s,I,k}^{H*} > \lambda^{H*}$, $\lambda_{f,k}^{H*} = \lambda^{H*} = 0$.
3. When $\gamma > \frac{(1-p)(1-\omega)h}{p(1-\tau-\omega h)+\omega h}\beta$, $\lambda_{s,I,k}^{H*} = \lambda_{s,I}^{H*}$, $\lambda_{s,T,k}^{H*} = \lambda_{s,T}^{H*}$ and $\lambda_{f,k}^{H*} = \lambda_f^{H*}$.

As with the result of the previous models, the tax cut reduces the tax cost associated with a coordination, so HQ starts inducing collaboration on the innovative project after the tax cut, if the project meets the inducing threshold after the tax cut as shown in Case 2. However, this result differs from the previous models in that the allocation increases only for the failure outcome but stays the same for the success outcome. Once HQ observes a success, contractable investment allows it to allocate all the capital to the low-tax subsidiary, regardless of the tax-rate differential. Another difference from the other models is Case 3. In previous models, the result shows that the general tax cut alleviates the internal incentive problem and allows HQ to allocate more to the low-tax subsidiary, whereas Case 3 of the current proposition shows that the general tax cut has no effect on capital allocation. This is not a surprising result, given that the optimal allocation does not refer to the tax-rate differential between the two subsidiaries, as discussed in Proposition 2.4 and again shown in Lemma 1.4.

5.4 Effect of a Specific Rate Reduction – Model Extension

In this section, I revisit the results for a rate reduction that is specific to innovation-related incomes, for the model extensions as outlined in Chapter 4. The effect of a specific rate reduction under the extended models differs in several aspects from that of the base model. Lemma 2.1 states the optimal allocation after the specific tax reduction for Model 1, when HQ allocates physical capital upfront to the subsidiaries, and the prototype outcome is not verifiable.

Lemma 2.1

For Model 1, the optimal allocation $(\lambda_k^{H*}, \lambda_k^{L*})$ after the specific rate reduction is characterized by:

1. $(\lambda_k^{H*}, \lambda_k^{L*}) = (0, \lambda)$ if $\gamma > \frac{1-\omega}{\omega}\beta$.
2. $(\lambda_k^{H*}, \lambda_k^{L*}) = (0, \lambda)$ if $\gamma < \frac{(1-\omega)(h-p(h-k))}{p(1-\tau-k)+\omega(h-p(h-k))}\beta$.
3. $(\lambda_k^{H*}, \lambda_k^{L*}) = (\lambda - s_{L,k}, s_{L,k})$ if $\frac{(1-\omega)(h-p(h-k))}{p(1-\tau-k)+\omega(h-p(h-k))}\beta < \gamma < \frac{1-\omega}{\omega}\beta$, where

$$s_{L,k} = \frac{\omega(\beta+\gamma)(1-\tau-k)}{\beta(1-\tau)-\omega(\beta+\gamma)k}\lambda$$

Like the general rate reduction, the specific tax reduction reduces the tax cost associated with inducing collaboration on the innovative project. However, unlike the general rate reduction, the benefit of the specific rate reduction is limited to successful innovations. In the model, if the prototype fails, the subsidiaries must default to traditional production that does not qualify for favorable tax treatment. As discussed in Bradley, Ruf, and Robinson (2018), traditional R&D incentives subsidize R&D input regardless of the outcome, whereas the patent-box regime rewards only successful outcomes, an important difference between the two types of R&D tax incentive. For this reason, the benefit of the specific rate reduction is smaller than the general rate reduction, for it has a probability of $1-p$ not to apply. One can see in Lemma 2.1 that the inducing threshold is lower than before the specific rate reduction, but higher than the inducing threshold of the general rate reduction as stated in Lemma 1.1.

I then compare the optimal allocation before and after the specific rate reduction to derive the changes in capital allocation in response to the tax policy. Proposition 6.1 states this result.

Proposition 6.1

1. When $\gamma > \frac{1-\omega}{\omega}\beta$ or $\gamma < \frac{(1-\omega)(h-p(h-k))}{p(1-\tau-k)+\omega(h-p(h-k))}\beta$, $\lambda_k^{H*} = \lambda^{H*}$.
2. When $\frac{(1-\omega)(h-p(h-k))}{p(1-\tau-k)+\omega(h-p(h-k))}\beta < \gamma < \frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta$, $\lambda_k^{H*} > \lambda^{H*}$.
3. When $\frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta < \gamma < \frac{1-\omega}{\omega}\beta$, $\lambda_k^{H*} < \lambda^{H*}$.

Except for the difference in its effect on the inducing threshold, the specific rate reduction otherwise has the same effect as the general rate reduction on the capital allocation. The first effect reduces the tax cost of inducing collaboration on the innovative project. One can see from Case 2 that HQ induces collaboration and allocates more capital to the high-tax subsidiary after the tax cut if the innovative opportunity meets the new inducing threshold. The second effect alleviates the internal incentive problem by allowing HQ to allocate more to the low-tax subsidiary. One can see from Case 3 that capital allocation decreases for the high-tax subsidiary when HQ finds the innovative opportunity worth inducing even prior to the tax cut.

I now turn my attention to Model 2, where HQ specifies an upfront contract of capital allocations that depend on the prototype outcome and the investment decision being non-contractable. Lemma 2.2 states the optimal allocation after the specific rate reduction, and Proposition 6.2 states the capital allocation changes following the specific rate reduction.

Lemma 2.2

For Model 2, the optimal allocation after the specific rate reduction is characterized by:

1. If $\gamma < \frac{(1-\omega)(h-p(h-k))}{p(1-\tau-k)+\omega\left(h-p(h-k)\right)}\beta$, inducing collaboration is not worthwhile, even after the specific rate reduction, and $(\lambda_k^{H*}, \lambda_k^{L*}) = (0, \lambda)$.
2. If $\frac{(1-\omega)(h-p(h-k))}{p(1-\tau-k)+\omega\left(h-p(h-k)\right)}\beta < \gamma$, the optimal allocation is:
    1. $(\lambda_{s,k}^{H*}, \lambda_{s,k}^{L*}, \lambda_{f,k}^{H*}, \lambda_{f,k}^{L*}) = (0, \lambda, 0, \lambda)$ if $\gamma > \frac{1-\omega}{\omega}\beta$.
    2. $(\lambda_{s,k}^{H*}, \lambda_{s,k}^{L*}, \lambda_{f,k}^{H*}, \lambda_{f,k}^{L*}) = (\lambda - s_{L,k}, s_{L,k}, \lambda - s_{L,k}, s_{L,k})$ if $\frac{(1-\omega)k}{p(1-\tau-k)+\omega k}\beta < \gamma < \frac{1-\omega}{\omega}\beta$,

    where

$$s_{L,k} = \frac{\omega(\beta+\gamma)(1-\tau-k)}{\beta(1-\tau)-\omega(\beta+\gamma)k}\lambda$$

Proposition 6.2

1. When $\gamma > \frac{1-\omega}{\omega}\beta$ or $\gamma < \frac{(1-\omega)(h-p(h-k))}{p(1-\tau-k)+\omega(h-p(h-k))}\beta$, $\lambda_k^{H*} = \lambda^{H*}$.
2. When $\frac{(1-\omega)(h-p(h-k))}{p(1-\tau-k)+\omega(h-p(h-k))}\beta < \gamma < \frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta$, $\lambda_k^{H*} > \lambda^{H*}$.
3. When $\frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta < \gamma < \frac{1-\omega}{\omega}\beta$, $\lambda_k^{H*} < \lambda^{H*}$.

Compared with the general rate reduction, the specific rate reduction has similar effects, namely, the reduction in the coordination cost reduces the inducing thresholds and alleviates the internal incentive problem. The second effect allows HQ to allocate more to the low-tax subsidiary and less to the high-tax subsidiary. In contrast, the extent to which the inducing threshold decreases is smaller for the specific tax cut than the general tax cut. This is because the benefit of the specific tax cut applies only to successful innovations.

Finally, I state the result for Model 4 where HQ specifies an upfront contract of the capital allocations that depend on the prototype outcome, and the investment decision is contractable. Lemma 2.4 states the optimal allocation after the specific rate reduction, and Proposition 6.4 states the capital allocation changes following the specific rate reduction.

Lemma 2.4

For Model 4, the optimal allocation after the specific tax reduction is characterized by:

1. If $\gamma < \frac{(1-p)(1-\omega)h}{p(1-\tau-\omega h)+\omega h}\beta$, inducing collaboration is not worthwhile, and $(\lambda_k^{H*}, \lambda_k^{L*}) = (0, \lambda)$.
2. If $\frac{(1-p)(1-\omega)h}{p(1-\tau-\omega h)+\omega h}\beta < \gamma$, the optimal allocation $(\lambda_{s,I,k}^{H*}, \lambda_{s,I,k}^{L*}, \lambda_{s,T,k}^{H*}, \lambda_{s,T,k}^{L*}, \lambda_{f.k}^{H*}, \lambda_{f,k}^{L*})$ is

   (a) If $\gamma > \frac{1-\omega}{\omega}\beta$,

$$(\lambda_{s,I,k}^{H*}, \lambda_{s,I,k}^{L*}, \lambda_{s,T,k}^{H*}, \lambda_{s,T,k}^{L*}, \lambda_{f.k}^{H*}, \lambda_{f,k}^{L*}) = \left(0, \lambda, \lambda_{s,T,k}^{H*}, \lambda_{s,T,k}^{L*}, 0, \lambda\right)$$

   where

$$\max\left\{0, \lambda - \frac{(1-\omega)(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau-h)}\right\} \leq \lambda_{s,T,k}^{L*} \leq \lambda$$

(b) If $\frac{(1-p)(1-\omega)h}{p(1-\tau-\omega h)+\omega h}\beta < \gamma < \frac{1-\omega}{\omega}\beta$,

$$(\lambda_{s,I,k}^{H*}, \lambda_{s,I,k}^{L*}, \lambda_{s,T,k}^{H*}, \lambda_{s,T,k}^{L*}, \lambda_{f.k}^{H*}, \lambda_{f,k}^{L*}) = \left(0, \lambda, \lambda_{s,T,k}^{H*}, \lambda_{s,T,k}^{L*}, \lambda - \frac{\omega(\beta+\gamma)}{\beta}\lambda, \frac{\omega(\beta+\gamma)}{\beta}\lambda\right)$$

where

$$\max\left\{0, \lambda - \frac{(1-\omega)(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau-h)}\right\} \leq \lambda_{s,T,k}^{L*} \leq \frac{\omega(\beta+\gamma)}{\beta}\lambda$$

Proposition 6.4

For Model 4, the specific rate reduction does not change the optimal capital allocation.

Comparing this result with the optimal allocation under Model 4 prior to the rate reduction, one can see that they are the same, both in terms of the inducing threshold and the allocation amounts. This is because the tax reduction applies only to the success outcome, and the income must be earned in the high-tax subsidiary. However, with the *Time 4* investment being contractable, HQ allocates all the capital to the low-tax subsidiary for the success outcome. As a result, when the prototype is a success, the tax rate of the high-tax subsidiary becomes irrelevant, rendering the specific rate reduction ineffective.

5.5 Summary

In summary, I consider the tax policy implications of the tradeoff between an MNC's objective to coordinate collaboration and its tax-planning objective. I study two types of tax policy that are used to promote innovative activities and attract capital investments, a general rate reduction that applies to both traditional and innovative projects, and a specific rate reduction that applies only to successful innovations (such as a patent-box regime). I study how an MNC changes its capital allocation to these tax incentives depending on its need to coordinate internal collaboration across subsidiaries. The model reveals two important insights. First, an

MNC does not always respond to a tax incentive, and this occurs under two scenarios. The first is when the tax incentive does not alter the costs or the benefits of the above tradeoff, and the second is when the tax incentive is not strong enough to reduce the cost associated with coordinating collaboration. Second, when the MNC does change its capital allocation in response to the tax policy, the change does not always conform to the policy's intention. The model shows that a tax cut from a high-tax country can unintentionally alleviate the internal coordination cost for an MNC and thereby allow the MNC to coordinate collaboration with a more tax-efficient allocation. This results in the MNC allocating less capital to a subsidiary in the high-tax country after the tax cut. These findings hold in the model extensions as well with slight variations. These results highlight the importance of the internal management of an MNC in affecting the MNC's response to external tax incentives.

Chapter 6. Conclusion

Multinational corporations face a unique set of business opportunities and managerial challenges. At the same time, the differences in the tax rules and rates across jurisdictions also present MNCs with a unique set of tax-planning opportunities. In the context of transferring physical goods across borders between subsidiaries, the literature has separately addressed the rich managerial implications and tax consequences of the transfer-pricing decision. As discussed in Chapter 2, several studies have considered the tradeoff between a managerial objective and a tax-planning objective. However, outside the context of the flow of physical goods and the transfer-pricing decision, the literature has not considered other important decisions that an MNC makes that could have implications in both realms.

As organizations increasingly rely on innovations and the integration of knowledge to derive competitive advantage, managing the flow of intangible resources becomes increasingly important. As subsidiaries play a more active strategic role, they gain unique experiences and become the owners of their intellectual capabilities. However, it is the collection and integration of these different capabilities that form an organization's overall competitive strategy. As a result, the headquarters plays a crucial role in the coordination of subsidiary-specific resources. The tacit nature of knowledge, expertise, and intellectual capabilities makes formal processes ineffective management tools. Direct monitoring has also been shown to be ineffective to facilitate knowledge-sharing, especially when creative effort is involved. In this context, subsidiary collaborations facilitate the flow of intangible resources by creating knowledge-sharing opportunities and promoting interactions within an innovation team.

In this thesis, I study a situation where the flow of intangible resources occurs through collaboration between two subsidiaries. Each subsidiary possesses different expertise that is critical to an innovation opportunity, so they must collaborate on the innovative project for it to succeed. The headquarters does not have direct control over each subsidiary's contribution of its intellectual resources. It is the central allocation of capital to the subsidiaries that serves a crucial role in achieving a coordinated outcome, as the capital allocation can incentivize both subsidiaries to participate in the innovative project. This is the managerial objective of the MNC's capital allocation decision. However, because the subsidiaries reside in different jurisdictions that charge different tax rates, the capital allocation decision also has a tax objective. The first task of this thesis is to characterize the tradeoff between the managerial and tax objectives.

A tradeoff occurs when the tax-minimizing allocation does not incentivize both subsidiaries to contribute to the innovative project. Because each subsidiary can earn a baseline return on its own traditional project, the more capital a subsidiary has, the more profits it can earn on its own in the traditional project. However, collaboration on the innovative project is appealing only if it offers the subsidiary a share of profits greater than the profits it can earn alone by itself. Therefore, the headquarters cannot allocate too much capital to either subsidiary for collaboration to occur. This concern for collaboration restricts the amount of tax savings the capital allocation can generate from the low-tax subsidiary. In this context, the difference in the tax rates between the subsidiaries creates a tax cost to the coordination of collaboration. The headquarters trades off this cost against the benefit of collaboration on the innovative project and would optimally forgo the innovation if the cost exceeds the benefit.

I first establish the tradeoff in the base model where a subsidiary's project choice entails the contribution of both types of resource. In the model extension, a subsidiary decides whether to contribute its intellectual resource and then decides on which project to invest. I accomplish this through introducing a prototype stage to the innovation project. This serves several purposes. First, the prototype stage is subject to a risk of failure, but the headquarters does not know whether the failure is due to chance or a lack of intellectual contribution. Second, it separates a subsidiary's intellectual contribution, that is most critical during the development stage, from its investment choice, that is most critical during the production stage. Finally, the prototype stage could produce an observable outcome which the capital allocation can contract upon. These extended versions of the model progressively relax the assumptions made in the base model, and the basic tradeoff appears in similar fashions in these model extensions.

The second task of this thesis is to examine how a multinational corporation's need for internal collaboration affects the way it changes its capital allocation because of a tax policy. I study two types of tax cut, one that applies to all types of business income and another that applies only to income earned from successful innovations. Both types of tax cut have been used in various countries to attract capital investments into innovations and promote R&D activities. This analysis reveals two important insights. First, although a tax cut reduces the coordination cost for an MNC, the MNC does not always change its behavior. This occurs if the cost reduction is not high enough or if its internal coordination cost does not depend on taxes to begin with. Second, when an MNC changes its behavior, it does not always change in the direction intended by the policy. A tax cut offers more profits to be shared in collaboration on the innovative project, and thereby alleviates the internal coordination problem and allows the MNC to allocate even more to the low-tax subsidiary. In this case, an MNC responds to a tax cut by reducing its capital allocated to the country giving the tax cut. These basic results hold across the variations of the model with slight differences when the tax cut applies only to income earned from successful innovations.

This thesis extends our understanding of the interaction between a multinational corporation’s managerial considerations and its tax objectives. First, the prior literature has examined a tradeoff between the two objectives in a context that involves the flow of physical goods. This thesis extends this inquiry by examining a context that involves the coordination of a flow of intangible goods in the form of tacit knowledge and expertise. Second, the prior literature generally focuses on the transfer-pricing decision between international subsidiaries. However, there are other important decisions that a multinational corporation makes that have implications in both realms. This thesis contributes to this inquiry by studying the capital allocation decision. Third, international business models have shifted from viewing the multinational corporation as a vertical hierarchy to viewing the entity as an interconnected network. In this network, each subsidiary serves a distinct role and possesses a distinct set of expertise and capabilities. This thesis extends our understanding of the coordination role of the headquarters by incorporating the lateral relationships among subsidiaries. Finally, this thesis extends the literature that examines tax incentives and R&D activities by exploring the innovation process itself and various stages throughout the innovation process.

This study has several implications for both managerial practices and tax policies. From the management perspective, while the different tax rates and rules provide multinational corporations unique tax-planning opportunities, they also create opportunity costs for internal coordination. This tax cost that is external to the corporation is an underexplored area in management. From a tax policy perspective, the tax policies that give rise to the tax-rate differential between two subsidiaries are likely formed by two independent countries. The tax disparity creates a coordination cost for a multinational corporation and affects its allocation of capital. Although tax laws are often drafted independently across countries, the subsidiaries that operate in the different countries are interrelated through the MNC's internal network. Finally, the internal coordination concerns may cause an MNC to respond to a tax policy in ways that are opposite to the stated policy intention. This thesis thus highlights the importance of understanding the interconnectedness of an MNC in assessing the effect of a tax incentive.

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Appendix: Proofs

Proof of Proposition 1

From the budget constraint, $\lambda^H = \lambda - \lambda^L$, and substitute it into the objective function:

$$(\beta + \gamma)\big((1 - \tau - h)\lambda^H + (1 - \tau)\lambda^L\big) = (\beta + \gamma)\big((1 - \tau - h)(\lambda - \lambda^L) + (1 - \tau)\lambda^L\big)$$

$$= (\beta + \gamma)((1 - \tau - h)\lambda + h\lambda^L)$$

One can see from this expression that the objective function is increasing in λ^L.

Next, substitute $\lambda^H = \lambda - \lambda^L$ into inequalities (1) and (2), and we have:

$$(1 - \omega)(\beta + \gamma)\big((1 - \tau - h)(\lambda - \lambda^L) + (1 - \tau)\lambda^L\big) \geq \beta(1 - \tau - h)(\lambda - \lambda^L) \qquad (1')$$

$$\omega(\beta + \gamma)\big((1 - \tau - h)(\lambda - \lambda^L) + (1 - \tau)\lambda^L\big) \geq \beta(1 - \tau)\lambda^L \qquad (2')$$

Solving inequality $(1')$ provides a *lower bound* of λ^L:

$$\lambda^L \geq \frac{\beta(1 - \tau - h) - (1 - \omega)(\beta + \gamma)(1 - \tau - h)}{(1 - \omega)(\beta + \gamma)h + \beta(1 - \tau - h)} \cdot \lambda$$

Rearranging inequality $(2')$,

$$\omega(\beta + \gamma)(1 - \tau - h)\lambda \geq (\beta(1 - \tau) - \omega(\beta + \gamma)h)\lambda^L \qquad (2'')$$

Case 1: when $\beta(1 - \tau) - \omega(\beta + \gamma)h \leq 0$, we have $\gamma \geq \frac{\beta(1-\tau-\omega h)}{\omega h}$, and the right hand side of $(2'')$ is negative while the left hand side is positive. Therefore, constraint (2) is satisfied for any λ^L and does not impose an upper bound on λ^L. However, the budget constraint enforces that $0 \leq \lambda^L \leq \lambda$.

With γ being the upper bound and the expression obtained in $(1')$ being the lower bound, we obtain a feasible range for λ^L:

$$\max\left\{\frac{\big(\beta - (1 - \omega)(\beta + \gamma)\big)(1 - \tau - h)}{(1 - \omega)(\beta + \gamma)h + \beta(1 - \tau - h)}\lambda, 0\right\} \leq \lambda^L \leq \lambda$$

We first verify that this range is non-empty by computing the following.

$$\lambda - \frac{\big(\beta-(1-\omega)(\beta+\gamma)\big)(1-\tau-h)}{(1-\omega)(\beta+\gamma)h+\beta(1-\tau-h)}\lambda = \frac{(1-\omega)(1-\tau)(\beta+\gamma)}{(1-\omega)(\beta+\gamma)h+\beta(1-\tau-h)} > 0$$

This shows that the upper bound of this range is strictly larger than the lower bound, hence the range is non-empty.

Recall that the objective function is increasing in λ^L, so the optimal λ^L takes the upper bound. In other words, $\lambda^{L*} = \lambda$.

Case 2: when $\beta(1-\tau)-\omega(\beta+\gamma)h > 0$, we have $\gamma < \frac{\beta(1-\tau-\omega h)}{\omega h}$, so one can divide $\beta(1-\tau)-\omega(\beta+\gamma)h$ from both sides of $(2'')$ to derive an upper bound of λ^L.

$$\lambda^L \le \frac{\omega(\beta+\gamma)(1-\tau-h)}{\beta(1-\tau)-\omega(\beta+\gamma)h}\lambda$$

Denote $s_L = \frac{\omega(\beta+\gamma)(1-\tau-h)}{\beta(1-\tau)-\omega(\beta+\gamma)h}\lambda$, and note that (2) is binding when $\lambda^L = s_L$.

Together with the budget constraint, one obtains a feasible range of λ^L

$$\max\left\{\frac{\big(\beta-(1-\omega)(\beta+\gamma)\big)(1-\tau-h)}{(1-\omega)(\beta+\gamma)h+\beta(1-\tau-h)}\lambda, 0\right\} \le \lambda^L \le \min\{s_L, \lambda\}$$

We first verify that this range is non-empty by computing

$$s_L - \frac{\big(\beta-(1-\omega)(\beta+\gamma)\big)(1-\tau-h)}{(1-\omega)(\beta+\gamma)h+\beta(1-\tau-h)}\lambda$$
$$= \frac{\beta\gamma(1-\tau)(1-\tau-h)}{\big(\beta(1-\tau)-\omega(\beta+\gamma)h\big)\big((1-\omega)(\beta+\gamma)h+\beta(1-\tau-h)\big)}\lambda > 0$$

and

$$s_L = \frac{\omega(\beta+\gamma)(1-\tau-h)}{\beta(1-\tau)-\omega(\beta+\gamma)h}\lambda > 0$$

where we use the case-2 condition that $\beta(1-\tau)-\omega(\beta+\gamma)h > 0$. This shows the range for λ^L is non-empty.

The upper bound of λ^L is $\min\{s_L, \lambda\}$ and is the allocation that maximizes the tax savings while maintaining the *Time 4* incentive compatible constraints, so the optimal λ^{L*} takes this upper bound.

Next, I derive the two sub-cases where $\min\{s_L, \lambda\} = s_L$ and where $\min\{s_L, \lambda\} = \lambda$ by computing the difference between λ and s_L:

$$\lambda - s_L = \frac{(1-\tau)\big((1-\omega)\beta - \omega\gamma\big)}{\beta(1-\tau) - \omega(\beta+\gamma)h}\lambda$$

Because $\beta(1-\tau) - \omega(\beta+\gamma)h > 0$ and $1-\tau > 0$, $\lambda - s_L$ has the same sign as $(1-\omega)\beta - \omega\gamma$.

Case 2.1: when $(1-\omega)\beta - \omega\gamma \leq 0$, we have $\gamma \geq \frac{1-\omega}{\omega}\beta$, and in this case, $s_L \geq \lambda$, so $\lambda^{L*} = \min\{s_L, \lambda\} = \lambda$.

Case 2.2: when $(1-\omega)\beta - \omega\gamma > 0$, we have $\gamma < \frac{1-\omega}{\omega}\beta$, and in this case, $s_L < \lambda$, so $\lambda^{L*} = \min\{s_L, \lambda\} = s_L$.

In summary,

$$\lambda^{L*} = \begin{cases} \lambda, if\ \gamma \geq \dfrac{\beta(1-\tau-\omega h)}{\omega h} \\ \lambda, if\ \gamma < \dfrac{\beta(1-\tau-\omega h)}{\omega h}\ and\ \gamma \geq \dfrac{1-\omega}{\omega}\beta \\ s_L, if\ \ \gamma < \dfrac{\beta(1-\tau-\omega h)}{\omega h}\ and\ \gamma < \dfrac{1-\omega}{\omega}\beta \end{cases}$$

One can combine the two cases where $\lambda_s^{L*} = \lambda$ because

$$\frac{\beta(1-\tau-\omega h)}{\omega h} - \frac{1-\omega}{\omega}\beta = \frac{\beta(1-\tau-h)}{\omega h} > 0$$

And we have $\frac{\beta(1-\tau-\omega h)}{\omega h} > \frac{1-\omega}{\omega}\beta$. Therefore, λ_s^{L*} can be described with

$$\lambda^{L*} = \begin{cases} \lambda, if\ \ \gamma \geq \dfrac{1-\omega}{\omega}\beta \\ s_L, if\ \gamma < \dfrac{1-\omega}{\omega}\beta \end{cases}$$

Proof of Proposition 2

After determining the optimal payoff for inducing collaboration on the innovative project, the headquarters compares it with the optimal payoff for not inducing it. This allows the headquarters to determine whether pursuing the innovative opportunity is worthwhile.

If the headquarters does not induce collaboration on the innovative project, the total payoff is:

$$\beta\big((1-\tau-h)\lambda^H+(1-\tau)\lambda^L\big)=\beta((1-\tau-h)\lambda+h\lambda^L)$$

Note that the total payoff increases in λ^L because a higher value of λ^L yields a higher tax saving, so the headquarters optimally allocates all the capital to the low-tax subsidiary when it forgoes the innovative project. In other words, $\lambda^{L*}=\lambda$ and $\lambda^{H*}=0$. The optimal payoff is thus $\beta(1-\tau)\lambda$.

The headquarters compares this payoff with the optimal payoff for inducing collaboration as given in the two cases of Proposition 1.

Case 1. $\gamma \geq \frac{1-\omega}{\omega}\beta$: the optimal allocation that induces collaboration is $\lambda^L=\lambda$ and $\lambda^H=0$, and the optimal payoff associated with this allocation is $(\beta+\gamma)(1-\tau)\lambda$. Inducing collaboration in this case has a higher optimal payoff, as $(\beta+\gamma)(1-\tau)\lambda > \beta(1-\tau)\lambda$, making it worthwhile.

Case 2. $\gamma < \frac{1-\omega}{\omega}\beta$: the optimal allocation that induces collaboration is $\lambda^L=s_L$ and $\lambda^H=\lambda-s_L$, and the optimal payoff associated with this allocation is

$$(\beta+\gamma)\big((1-\tau-h)(\lambda-s_L)+(1-\tau)s_L\big)=\frac{(1-\tau)(1-\tau-h)(\beta+\gamma)\lambda}{\beta(1-\tau)-\omega(\beta+\gamma)h}$$

The difference between this payoff and that for not inducing collaboration is:

$$(\beta+\gamma)\big((1-\tau-h)(\lambda-s_L)+(1-\tau)s_L\big)-\beta(1-\tau)\lambda$$
$$=\frac{\beta(1-\tau)((1-\tau-(1-\omega)h)\gamma-h\beta(1-\omega))}{\beta(1-\tau)-\omega(\beta+\gamma)h}\lambda$$

When $\gamma<\frac{1-\omega}{\omega}\beta$, $(1-\tau)-\omega(\beta+\gamma)h>0$, and the difference is positive if and only if

$$(1-\tau-(1-\omega)h)\gamma-h\beta(1-\omega)>0$$

that is equivalent to

$$\gamma>\frac{(1-\omega)h}{1-\tau-(1-\omega)h}\beta$$

This lower bound of γ together with the upper bound that defines case 2 produces a range for γ.

One can check that the range is non-empty by computing the following.

$$\frac{1-\omega}{\omega}\beta - \frac{(1-\omega)h}{1-\tau-(1-\omega)h}\cdot\beta = \frac{(1-\omega)(1-\tau-h)}{\omega(1-\tau-(1-\omega)h)}\beta > 0$$

Therefore, in case 2, inducing collaboration is worthwhile if and only if $\gamma > \frac{(1-\omega)h}{1-\tau-(1-\omega)h}\beta$.

In summary, when $\gamma \geq \frac{1-\omega}{\omega}\beta$, the first-best solution is obtained, and the headquarters induces collaboration with no additional tax cost. It maximizes tax savings by allocating $\lambda^{L*} = \lambda$ and $\lambda^{H*} = 0$.

When $\frac{(1-\omega)h}{1-\tau-(1-\omega)h}\beta < \gamma < \frac{1-\omega}{\omega}\beta$, inducing collaboration has a tax cost, but its benefit outweighs the cost, and the optimal allocation induces collaboration at the lowest tax cost. Following proposition 1, this optimal allocation is $(\lambda^{H*}, \lambda^{L*}) = (\lambda - s_L, s_L)$.

Finally, when $\gamma < \frac{(1-\omega)h}{1-\tau-(1-\omega)h}\beta$, inducing collaboration is not worthwhile, and the optimal allocation is $\lambda^{L*} = \lambda$ and $\lambda^{H*} = 0$.

Proof of Proposition 1.1

From the budget constraint, $\lambda^H = \lambda - \lambda^L$, and substitute it into the objective function:

$$p(\beta+\gamma)\big((1-\tau-h)\lambda^H + (1-\tau)\lambda^L\big) + (1-p)\beta\big((1-\tau-h)\lambda^H + (1-\tau)\lambda^L\big)$$

$$= p(\beta+\gamma)\big((1-\tau-h)(\lambda-\lambda^L) + (1-\tau)\lambda^L\big) + (1-p)\beta\big((1-\tau-h)(\lambda-\lambda^L) + (1-\tau)\lambda^L\big)$$

$$= p(\beta+\gamma)\big((1-\tau-h)\lambda + h\lambda^L\big) + (1-p)\beta\big((1-\tau-h)\lambda + h\lambda^L\big)$$

One can see from this expression that the objective function is increasing in λ^L.

Next, substitute $\lambda^H = \lambda - \lambda^L$ into inequalities (1) and (2), and we have:

$$(1-\omega)(\beta+\gamma)\big((1-\tau-h)(\lambda-\lambda^L) + (1-\tau)\lambda^L\big) \geq \beta(1-\tau-h)(\lambda-\lambda^L) \qquad (1')$$

$$\omega(\beta+\gamma)\big((1-\tau-h)(\lambda-\lambda^L) + (1-\tau)\lambda^L\big) \geq \beta(1-\tau)\lambda^L \qquad (2')$$

Notice that ($1'$) and ($2'$) are equivalent to inequalities (3) and (4), so the inequalities (1) and (2) are redundant. Therefore, the feasible region of LP-1 can be described solely by inequalities (3) to (6). Comparing this feasible region with that of LP-Base, one can see that they are the same, so the feasible range for λ^L is the same. Furthermore, because the objective function increases in λ^L, the optimal solution takes the upper bound of λ^L. One can refer to the proof of Proposition 1 to check for the non-emptiness of the range derived for λ^L. It follows that the optimal solution is the same as that of LP-Base.

Proof of Proposition 2.1

As with Proposition 2, after determining the optimal payoff for inducing collaboration on the innovative project, the headquarters compares it with the optimal payoff for not inducing it. This allows the headquarters to determine whether pursuing the innovative opportunity is worthwhile.

From the proof of Proposition 2, the optimal payoff for not inducing collaboration is $\beta(1-\tau)\lambda$.

The headquarters compares this payoff with the optimal payoff for inducing collaboration as given in the two cases of Proposition 1.1.

Case 1. $\gamma \geq \frac{1-\omega}{\omega}\beta$: the optimal allocation that induces collaboration is $\lambda^L = \lambda$ and $\lambda^H = 0$, and the optimal payoff associated with this allocation is $p(\beta+\gamma)(1-\tau)\lambda + (1-p)\beta(1-\tau)\lambda$. Inducing collaboration in this case has a higher payoff, as $p(\beta+\gamma)(1-\tau)\lambda + (1-p)\beta(1-\tau)\lambda > \beta(1-\tau)\lambda$, making it worthwhile.

Case 2. $\gamma < \frac{1-\omega}{\omega}\beta$: the optimal allocation that induces collaboration is $\lambda^L = s_L$ and $\lambda^H = \lambda - s_L$, and the optimal payoff associated with this allocation is

$$p(\beta+\gamma)\big((1-\tau-h)(\lambda-s_L)+(1-\tau)s_L\big)+(1-p)\beta\big((1-\tau-h)(\lambda-s_L)+(1-\tau)s_L\big)$$
$$=\frac{(1-\tau)(1-\tau-h)(\beta+p\gamma)\lambda}{\beta(1-\tau)-\omega(\beta+\gamma)h}$$

The difference between this payoff and that for not inducing collaboration is:

$$\frac{(1-\tau)(1-\tau-h)(\beta+p\gamma)\lambda}{\beta(1-\tau)-\omega(\beta+\gamma)h}-\beta(1-\tau)\lambda$$
$$=\frac{\beta(1-\tau)\big((p(1-\tau-h)+\omega h)\gamma-h\beta(1-\omega)\big)}{\beta(1-\tau)-\omega(\beta+\gamma)h}\lambda$$

When $\gamma<\frac{1-\omega}{\omega}\beta$, $(1-\tau)-\omega(\beta+\gamma)h>0$. This difference is positive if and only if

$$(p(1-\tau-h)+\omega h)\gamma-h\beta(1-\omega)>0$$

that is equivalent to

$$\gamma>\frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta$$

This lower bound of γ together with the upper bound that defines case 2 produces a range for γ.

One can check that the range is non-empty by computing the following.

$$\frac{1-\omega}{\omega}\beta-\frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta=\frac{(1-\omega)(1-\tau-h)}{\omega(p(1-\tau-h)+\omega h)}\beta>0$$

Therefore, in case 2, inducing collaboration is worthwhile if and only if $\gamma>\frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta$.

In summary, when $\gamma\geq\frac{1-\omega}{\omega}\beta$, the first best solution is obtained, and the headquarters induces collaboration with no additional tax cost. It maximizes tax savings by allocating $\lambda^{L*}=\lambda$ and $\lambda^{H*}=0$.

When $\frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta<\gamma<\frac{1-\omega}{\omega}\beta$, inducing collaboration has a tax cost, but its benefit outweighs the cost, and the optimal allocation induces collaboration at the lowest tax cost. Following proposition 1.1A, this optimal allocation is $(\lambda^{H*},\lambda^{L*})=(\lambda-s_L,s_L)$.

Finally, when $\gamma<\frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta$, inducing collaboration is not worthwhile, and the optimal allocation is $\lambda^{L*}=\lambda$ and $\lambda^{H*}=0$.

Proof of Proposition 1.2

Let us begin with computing λ_s^{L*} and λ_s^{H*}

Substitute $\lambda_s^H = \lambda - \lambda_s^L$ into (3) and (4), and we obtain

$$(1-\omega)(\beta+\gamma)\big((1-\tau-h)(\lambda-\lambda_s^L)+(1-\tau)\lambda_s^L\big) \geq \beta(1-\tau-h)(\lambda-\lambda_s^L) \quad (3')$$

$$\omega(\beta+\gamma)\big((1-\tau-h)(\lambda-\lambda_s^L)+(1-\tau)\lambda_s^L\big) \geq \beta(1-\tau)\lambda_s^L \quad (4')$$

Solving $(3')$ derives a lower bound of λ_s^L:

$$\lambda_s^L \geq \frac{(\beta-(1-\omega)(\beta+\gamma))(1-\tau-h)}{(1-\omega)(\beta+\gamma)h+\beta(1-\tau-h)} \cdot \lambda$$

Rearranging $(4')$ by moving all the terms of λ_s^L to the RHS

$$\omega(\beta+\gamma)(1-\tau-h)\lambda \geq (\beta(1-\tau)-\omega(\beta+\gamma)h)\lambda_s^L \quad (4'')$$

Case 1: when $\beta(1-\tau)-\omega(\beta+\gamma)h \leq 0$, we have $\gamma \geq \frac{\beta(1-\tau-\omega h)}{\omega h}$, and the right hand side of $(4'')$ is negative while the left hand side is positive. Therefore, constraint (4) is satisfied for any λ_s^L and does not impose an upper bound on λ_s^L. However, the budget constraint enforces that $0 \leq \lambda_s^L \leq \lambda$.

Together with $(3')$, we obtain the following range for λ_s^L.

$$\max\left\{\frac{\big(\beta-(1-\omega)(\beta+\gamma)\big)(1-\tau-h)}{(1-\omega)(\beta+\gamma)h+\beta(1-\tau-h)}\lambda, 0\right\} \leq \lambda_s^L \leq \lambda$$

We first verify that this range is non-empty by computing that

$$\lambda - \frac{\big(\beta-(1-\omega)(\beta+\gamma)\big)(1-\tau-h)}{(1-\omega)(\beta+\gamma)h+\beta(1-\tau-h)}\lambda = \frac{(1-\omega)(1-\tau)(\beta+\gamma)}{(1-\omega)(\beta+\gamma)h+\beta(1-\tau-h)} > 0$$

This shows that the upper bound of this range is strictly larger than the lower bound, hence the range is non-empty. Therefore, the optimal λ_s^{L*} takes the upper bound value $\lambda_s^{L*} = \lambda$.

Case 2: when $\beta(1-\tau)-\omega(\beta+\gamma)h > 0$, we have $\gamma < \frac{\beta(1-\tau-\omega h)}{\omega h}$, so one can divide $\beta(1-\tau)-\omega(\beta+\gamma)h$ from both sides of $(4')$ to derive an upper bound of λ_s^L.

$$\lambda_s^L \leq \frac{\omega(\beta+\gamma)(1-\tau-h)}{\beta(1-\tau)-\omega(\beta+\gamma)h}\lambda$$

Denote $s_L = \frac{\omega(\beta+\gamma)(1-\tau-h)}{\beta(1-\tau)-\omega(\beta+\gamma)h}\lambda$, and note that (4) is binding when $\lambda_s^L = s_L$. Together with the budget constraint, one obtains a range of λ_s^L

$$\max\left\{\frac{\big(\beta-(1-\omega)(\beta+\gamma)\big)(1-\tau-h)}{(1-\omega)(\beta+\gamma)h+\beta(1-\tau-h)}\lambda, 0\right\} \leq \lambda_s^L \leq \min\{s_L, \lambda\}$$

Let us first verify that this range is non-empty by computing

$$s_L - \frac{\big(\beta-(1-\omega)(\beta+\gamma)\big)(1-\tau-h)}{(1-\omega)(\beta+\gamma)h+\beta(1-\tau-h)}\lambda$$

$$= \frac{\beta\gamma(1-\tau)(1-\tau-h)}{\big(\beta(1-\tau)-\omega(\beta+\gamma)h\big)\big((1-\omega)(\beta+\gamma)h+\beta(1-\tau-h)\big)}\lambda > 0$$

and

$$s_L = \frac{\omega(\beta+\gamma)(1-\tau-h)}{\beta(1-\tau)-\omega(\beta+\gamma)h}\,\lambda > 0$$

where we use the case-2 condition that $\beta(1-\tau)-\omega(\beta+\gamma)h > 0$. This shows the range for λ_s^L is non-empty.

The upper bound of $\min\{s_L, \lambda\}$ for λ_s^L is the allocation that maximizes the tax savings while maintaining the *Time 4* incentive compatible constraints, so the optimal λ_s^{L*} takes this upper bound.

Next, one can derive the two subcases where $\min\{s_L, \lambda\} = s_L$ and where $\min\{s_L, \lambda\} = \lambda$ by computing the difference between λ and s_L:

$$\lambda - s_L = \frac{(1-\tau)\big((1-\omega)\beta-\omega\gamma\big)}{\beta(1-\tau)-\omega(\beta+\gamma)h}\lambda$$

Because $\beta(1-\tau)-\omega(\beta+\gamma)h > 0$ and $1-\tau > 0$, $\lambda - s_L$ has the same sign as $(1-\omega)\beta - \omega\gamma$.

Case 2.1: when $(1-\omega)\beta-\omega\gamma \leq 0$, we have $\gamma \geq \frac{1-\omega}{\omega}\beta$, and in this case, $s_L \geq \lambda$, so $\lambda_s^{L*} = \min\{s_L, \lambda\} = \lambda$.

Case 2.2: when $(1-\omega)\beta-\omega\gamma > 0$, we have $\gamma < \frac{1-\omega}{\omega}\beta$, and in this case, $s_L < \lambda$, so $\lambda_s^{L*} = \min\{s_L, \lambda\} = s_L$.

In summary,

$$\lambda_s^{L*} = \begin{cases} \lambda, if\ \gamma \geq \dfrac{\beta(1-\tau-\omega h)}{\omega h} \\ \lambda, if\ \gamma < \dfrac{\beta(1-\tau-\omega h)}{\omega h}\ and\ \gamma \geq \dfrac{1-\omega}{\omega}\beta \\ s_L, if\ \ \gamma < \dfrac{\beta(1-\tau-\omega h)}{\omega h}\ and\ \gamma < \dfrac{1-\omega}{\omega}\beta \end{cases}$$

One can combine the two cases where $\lambda_s^{L*} = \lambda$ because

$$\frac{\beta(1-\tau-\omega h)}{\omega h} - \frac{1-\omega}{\omega}\beta = \frac{\beta(1-\tau-h)}{\omega h} > 0$$

And we have $\frac{\beta(1-\tau-\omega h)}{\omega h} > \frac{1-\omega}{\omega}\beta$. Therefore, λ_s^{L*} can be described with

$$\lambda_s^{L*} = \begin{cases} \lambda, if\ \ \gamma \geq \dfrac{1-\omega}{\omega}\beta \\ s_L, if\ \gamma < \dfrac{1-\omega}{\omega}\beta \end{cases}$$

Next, let us compute λ_f^{L*} and λ_f^{H*}.

Rearranging inequality (1) shows that it is equivalent to

$$(1-\omega)(\beta+\gamma)\big((1-\tau-h)\lambda_s^H + (1-\tau)\lambda_s^L\big) \geq \beta(1-\tau-h)(\lambda - \lambda_f^L) \qquad (1')$$

This leads to a lower bound for λ_f^L:

$$\lambda_f^L \geq \lambda - \frac{(1-\omega)(\beta+\gamma)\big((1-\tau-h)\lambda_s^H + (1-\tau)\lambda_s^L\big)}{\beta(1-\tau-h)}$$

Rearranging inequality (2) shows that it is equivalent to

$$\omega(\beta+\gamma)\big((1-\tau-h)\lambda_s^H + (1-\tau)\lambda_s^L\big) \ \geq \beta(1-\tau)\lambda_f^L \qquad (2')$$

Dividing $\beta(1-\tau)$ from both sides of $(2')$, and we have

$$\lambda_f^L \leq \frac{\omega(\beta+\gamma)\big((1-\tau-h)\lambda_s^H + (1-\tau)\lambda_s^L\big)}{\beta(1-\tau)}$$

Together with the budget constraints, we obtain the range

$$\lambda_f^L \geq \max\left\{\lambda - \frac{(1-\omega)(\beta+\gamma)\big((1-\tau-h)\lambda_s^H + (1-\tau)\lambda_s^L\big)}{\beta(1-\tau-h)}, 0\right\}$$

$$\lambda_f^L \leq \min\left\{\frac{\omega(\beta+\gamma)\big((1-\tau-h)\lambda_s^H + (1-\tau)\lambda_s^L\big)}{\beta(1-\tau)}, \lambda\right\}$$

When $\gamma \geq \frac{1-\omega}{\omega}\beta$, $\lambda_s^{L*} = \lambda$ and $\lambda_s^{H*} = 0$. Substitute into the range for λ_f^L and we obtain that

$$\max\left\{\lambda - \frac{(1-\omega)(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau-h)}, 0\right\} \leq \lambda_f^L \leq \min\left\{\frac{\omega(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau)}, \lambda\right\}$$

One can simplify the upper bound by showing that $\min\left\{\frac{\omega(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau)}, \lambda\right\} = \lambda$. Since $\gamma \geq \frac{1-\omega}{\omega}\beta$, we have $\omega(\beta+\gamma) \geq \beta$, and

$$\frac{\omega(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau)} = \frac{\omega(\beta+\gamma)\lambda}{\beta} \geq \lambda$$

Next, let us verify that the range for λ_f^L is non-empty by showing that $\lambda - \frac{(1-\omega)(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau-h)} < \lambda$. This is clearly true because the LHS subtract a positive quantity from λ.

Because higher values of λ_f^L results in higher tax savings, the optimal solution $\lambda_f^{L*} = \lambda$.

When $\gamma < \frac{1-\omega}{\omega}\beta$, substitute $\lambda_s^{L*} = s_L$ and $\lambda_s^{H*} = \lambda - s_L$ into the range of λ_f^L,

$$\lambda_f^L \geq \max\left\{\lambda - \frac{(1-\omega)(\beta+\gamma)\big((1-\tau-h)(\lambda-s_L)+(1-\tau)s_L\big)}{\beta(1-\tau-h)}, 0\right\}$$

$$\lambda_f^L \leq \min\left\{\frac{\omega(\beta+\gamma)\big((1-\tau-h)(\lambda-s_L)+(1-\tau)s_L\big)}{\beta(1-\tau)}, \lambda\right\}$$

One can simplify the two bounds by first recalling that inequality (4) is binding at $\lambda_f^L = s_L$. In other words, when $\lambda_s^L = s_L$, and $\lambda_s^H = \lambda - s_L$, inequality (4) becomes an equality, so we can write:

$$\omega(\beta+\gamma)\big((1-\tau-h)(\lambda-s_L)+(1-\tau)s_L\big) = \beta(1-\tau)s_L$$

Rearrange the two bounds of λ_f^L with the above expression to get:

$$\lambda_f^L \geq \max\left\{\lambda - \frac{(1-\omega)\beta(1-\tau)s_L}{\omega\beta(1-\tau-h)}, 0\right\}$$

$$\lambda_f^L \leq \min\left\{\frac{\beta(1-\tau)s_L}{\beta(1-\tau)}, \lambda\right\} = \min\{s_L, \lambda\} = s_L$$

Next, let us verify that this range is non-empty by computing that

$$s_L - \left(\lambda - \frac{(1-\omega)\beta(1-\tau)s_L}{\omega\beta(1-\tau-h)}\right) = \frac{\gamma(1-\tau)\lambda}{\beta(1-\tau)-\omega(\beta+\gamma)h} > 0$$

Here, we applied that $\beta(1-\tau)-\omega(\beta+\gamma)h>0$. This is because

$$\gamma<\frac{1-\omega}{\omega}\beta<\frac{\beta(1-\tau-\omega h)}{\omega h}$$

So that

$$\beta(1-\tau)-\omega(\beta+\gamma)h=\beta(1-\tau-\omega h)-\omega h\gamma>0$$

Therefore, the lower bound for λ_f^L is strictly less than s_L. Again, a higher value of λ_f^L results in higher tax savings, so the optimal solution $\lambda_f^{L*}=s_L$ and $\lambda_f^{H*}=\lambda-s_L$. Note that inequality (2) is binding because $\lambda_f^{L*}=s_L$ takes the upper bound given by inequality (2). Furthermore, inequality (1) has slack because s_L is strictly greater than the lower bound given by inequality (1).

Proof of Proposition 2.2

As with Proposition 2, after determining the optimal payoff for inducing collaboration on the innovative project, the headquarters compares it with the optimal payoff for not inducing it. This allows the headquarters to determine whether pursuing the innovative opportunity is worthwhile.

From the proof of Proposition 2, the optimal payoff for not inducing collaboration is $\beta(1-\tau)\lambda$.

The headquarters compares this payoff with the optimal payoff for inducing collaboration as given in the two cases of Proposition 1.2.

Case 1. $\gamma\geq\frac{1-\omega}{\omega}\beta$: the optimal allocation that induces collaboration is $\lambda_f^L=\lambda_s^L=\lambda$ and $\lambda_f^H=\lambda_s^H=0$, and the optimal payoff associated is $p(\beta+\gamma)(1-\tau)\lambda+(1-p)\beta(1-\tau)\lambda$. Inducing collaboration in this case has a higher optimal payoff, as $p(\beta+\gamma)(1-\tau)\lambda+(1-p)\beta(1-\tau)\lambda>\beta(1-\tau)\lambda$, making it worthwhile.

Case 2. $\gamma<\frac{1-\omega}{\omega}\beta$: the optimal allocation that induces collaboration is $\lambda_f^L=\lambda_s^L=s_L$ and $\lambda_f^H=\lambda_s^H=\lambda-s_L$, and the optimal payoff associated with this allocation is

$$p(\beta+\gamma)\big((1-\tau-h)(\lambda-s_L)+(1-\tau)s_L\big)+(1-p)\beta\big((1-\tau-h)(\lambda-s_L)+(1-\tau)s_L\big)$$
$$=\frac{(1-\tau)(1-\tau-h)(\beta+p\gamma)\lambda}{\beta(1-\tau)-\omega(\beta+\gamma)h}$$

The difference between this payoff and that for not inducing collaboration is:

$$\frac{(1-\tau)(1-\tau-h)(\beta+p\gamma)\lambda}{\beta(1-\tau)-\omega(\beta+\gamma)h}-\beta(1-\tau)\lambda$$
$$=\frac{\beta(1-\tau)\big((p(1-\tau-h)+\omega h)\gamma-h\beta(1-\omega)\big)}{\beta(1-\tau)-\omega(\beta+\gamma)h}\lambda$$

When $\gamma < \frac{1-\omega}{\omega}\beta$, $(1-\tau)-\omega(\beta+\gamma)h > 0$, and the difference is positive if and only if

$$(p(1-\tau-h)+\omega h)\gamma - h\beta(1-\omega) > 0$$

that is equivalent to

$$\gamma > \frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta$$

This lower bound of γ together with the upper bound that defines case 2 produces a range for γ.

One can check that the range is non-empty by computing the following.

$$\frac{1-\omega}{\omega}\beta - \frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta = \frac{(1-\omega)(1-\tau-h)}{\omega(p(1-\tau-h)+\omega h)}\beta > 0$$

Therefore, in case 2, inducing collaboration is worthwhile if and only if $\gamma > \frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta$.

In summary, when $\gamma \geq \frac{1-\omega}{\omega}\beta$, first-best is obtained, and the headquarters induces collaboration with no additional tax cost. It maximizes tax savings by allocating $(\lambda_S^{H*}, \lambda_S^{L*}, \lambda_f^{H*}, \lambda_f^{L*}) = (0, \lambda, 0, \lambda)$.

When $\frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta < \gamma < \frac{1-\omega}{\omega}\beta$, inducing collaboration has a tax cost, but its benefit outweighs the cost, and the optimal allocation induces collaboration at the lowest tax cost. Following proposition 1.2A, this optimal allocation $(\lambda_S^{H*}, \lambda_S^{L*}, \lambda_f^{H*}, \lambda_f^{L*}) = (\lambda - s_L, s_L, \lambda - s_L, s_L)$.

Finally, when $\gamma < \frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta$, inducing collaboration is not worthwhile, and the optimal allocation is $\lambda^{L*} = \lambda$ and $\lambda^{H*} = 0$. Note that this allocation does not refer to the prototype outcome, because the headquarters decides not to pursue the innovative opportunity.

Proof of Proposition 1.3

When $\gamma \geq \frac{1-\omega}{\omega}\beta$, we can first verify that the first best solution $\left(\lambda_s^H, \lambda_s^L, \lambda_f^H, \lambda_f^L\right) = (0, \lambda, 0, \lambda)$ is feasible. Inequality (1) and (3) are clearly satisfied because the RHS are zero while the LHS are non-negative. For, inequality (2), because $\gamma \geq \frac{1-\omega}{\omega}\beta$, we have $\beta \leq \omega(\beta + \gamma)$ and

$$LHS = \omega(\beta + \gamma)(1 - \tau)\lambda \geq \beta(1 - \tau)\lambda = RHS$$

Similarly, for inequality (4), plug in $\left(\lambda_s^H, \lambda_s^L, \lambda_f^H, \lambda_f^L\right) = (0, \lambda, 0, \lambda)$, and we have

$$LHS = \omega(\beta + \gamma)(1 - \tau)\lambda \geq \beta(1 - \tau)\lambda = RHS$$

Therefore, the first best solution $\left(\lambda_s^H, \lambda_s^L, \lambda_f^H, \lambda_f^L\right) = (0, \lambda, 0, \lambda)$ is feasible must be optimal. In this case, the budget constraints (5) and (6) are clearly binding.

When $\gamma < \frac{1-\omega}{\omega}\beta$, we first show that $\left(\lambda_s^H, \lambda_s^L, \lambda_f^H, \lambda_f^L\right) = (\lambda - s_L, s_L, \lambda - s_L, s_L)$ is feasible. Because the solution is feasible to LP-2, it satisfies (5) and (6) at equality, and it satisfies all the other constraints that are the same between LP-2 and LP-3.

Next, we show that $\left(\lambda_s^H, \lambda_s^L, \lambda_f^H, \lambda_f^L\right) = (\lambda - s_L, s_L, \lambda - s_L, s_L)$ is optimal to LP-3.

Frist, any feasible solution to LP-3 must satisfy $\lambda_s^L \leq s_L$. We show this by substituting the budget constraint (5), $\lambda_s^H \leq \lambda - \lambda_s^L$, into inequality (4).

$$\begin{aligned}\beta(1 - \tau)\lambda_s^L &\leq \omega(\beta + \gamma)\big((1 - \tau - h)\lambda_s^H + (1 - \tau)\lambda_s^L\big) \\ &\leq \omega(\beta + \gamma)\big((1 - \tau - h)(\lambda - \lambda_s^L) + (1 - \tau)\lambda_s^L\big) \\ &= \omega(\beta + \gamma)\big((1 - \tau - h)\lambda + h\lambda_s^L\big)\end{aligned}$$

Rearranging the above, we have

$$(\beta(1 - \tau) - \omega(\beta + \gamma)h)\lambda_s^L \leq \omega(\beta + \gamma)(1 - \tau - h)\lambda$$

Because $\gamma < \frac{1-\omega}{\omega}\beta$, we have $\beta(1 - \tau) - \omega(\beta + \gamma)h > 0$, a quantity that can be divided from both sides of the above inequality to obtain:

$$\lambda_s^L \leq \frac{\omega(\beta+\gamma)(1-\tau-h)\lambda}{\beta(1-\tau)-\omega(\beta+\gamma)h} = s_L$$

This proves our first claim that any feasible solution to LP-3 must satisfy $\lambda_s^L \leq s_L$.

Second, any feasible solution to LP-3 must also satisfy $\lambda_f^L \leq s_L$. We show it by rearranging inequality (2) to the following:

$$\omega(\beta+\gamma)\big((1-\tau-h)\lambda_s^H + (1-\tau)\lambda_s^L\big) \geq \beta(1-\tau)\lambda_f^L \qquad (2')$$

Dividing $\beta(1-\tau)$ from both sides, and we have

$$\lambda_f^L \leq \frac{\omega(\beta+\gamma)\big((1-\tau-h)\lambda_s^H + (1-\tau)\lambda_s^L\big)}{\beta(1-\tau)}$$

Substituting the budget constraint (5), $\lambda_s^H \leq \lambda - \lambda_s^L$, into the above expression, we have:

$$\lambda_f^L \leq \frac{\omega(\beta+\gamma)\big((1-\tau-h)\lambda_s^H + (1-\tau)\lambda_s^L\big)}{\beta(1-\tau)} \leq \frac{\omega(\beta+\gamma)\big((1-\tau-h)(\lambda-\lambda_s^L) + (1-\tau)\lambda_s^L\big)}{\beta(1-\tau)}$$

$$= \frac{\omega(\beta+\gamma)\big((1-\tau-h)\lambda + h\lambda_s^L\big)}{\beta(1-\tau)}$$

We have just proved in the first statement that $\lambda_s^L \leq s_L$, so we can rewrite the above expression

$$\lambda_f^L \leq \frac{\omega(\beta+\gamma)\big((1-\tau-h)\lambda + h\lambda_s^L\big)}{\beta(1-\tau)} \leq \frac{\omega(\beta+\gamma)\big((1-\tau-h)\lambda + hs_L\big)}{\beta(1-\tau)}$$

One can show that the RHS of the above expression is s_L. Frist, recall that

$$s_L = \frac{\omega(\beta+\gamma)(1-\tau-h)}{\beta(1-\tau)-\omega(\beta+\gamma)h}\lambda$$

Multiplying $(\beta(1-\tau)-\omega(\beta+\gamma)h)$ to both sides, and one obtains

$$(\beta(1-\tau)-\omega(\beta+\gamma)h)s_L = \omega(\beta+\gamma)(1-\tau-h)\lambda$$

Adding $\omega(\beta+\gamma)hs_L$ to both sides, and one obtains

$$\beta(1-\tau)s_L = \omega(\beta+\gamma)\big((1-\tau-h)\lambda + hs_L\big)$$

Dividing $\beta(1-\tau)$ from both sides, and one obtains

$$\frac{\omega(\beta+\gamma)\big((1-\tau-h)\lambda+hs_L\big)}{\beta(1-\tau)}=s_L$$

This proves the second claim that any feasible solution to LP-3 must satisfy $\lambda_f^L \leq s_L$.

Finally, one can derive an upper bound of the objective value and show that this upper bound is achieved by $\left(\lambda_s^H,\lambda_s^L,\lambda_f^H,\lambda_f^L\right)=(\lambda-s_L,s_L,\lambda-s_L,s_L)$.

Substitute the budget constraints, $\lambda_s^H \leq \lambda-\lambda_s^L$ and $\lambda_f^H \leq \lambda-\lambda_f^L$, into the objective function.

$$p(\beta+\gamma)\big((1-\tau-h)\lambda_s^H+(1-\tau)\lambda_s^L\big)+(1-p)\beta\left((1-\tau-h)\lambda_f^H+(1-\tau)\lambda_f^L\right)$$

$$\leq p(\beta+\gamma)\big((1-\tau-h)(\lambda-\lambda_s^L)+(1-\tau)\lambda_s^L\big)$$

$$+(1-p)\beta\left((1-\tau-h)\big(\lambda-\lambda_f^L\big)+(1-\tau)\lambda_f^L\right)$$

$$\leq p(\beta+\gamma)\big((1-\tau-h)\lambda+h\lambda_s^L\big)+(1-p)\beta\left((1-\tau-h)\lambda+h\lambda_f^L\right)$$

Next, substitute the first and second claim, $\lambda_s^L \leq s_L$ and $\lambda_f^L \leq s_L$, into the above expression:

$$obj \leq p(\beta+\gamma)\big((1-\tau-h)\lambda+hs_L\big)+(1-p)\beta\big((1-\tau-h)\lambda+hs_L\big)$$

We then plug the feasible solution $\left(\lambda_s^H,\lambda_s^L,\lambda_f^H,\lambda_f^L\right)=(\lambda-s_L,s_L,\lambda-s_L,s_L)$ into the objective function and show that it achieves the upper bound shown above.

$obj(\lambda-s_L,s_L,\lambda-s_L,s_L)$

$=p(\beta+\gamma)\big((1-\tau-h)(\lambda-s_L)+(1-\tau)s_L\big)+(1-p)\beta\big((1-\tau-h)(\lambda-s_L)+(1-\tau)s_L\big)$

$=p(\beta+\gamma)\big((1-\tau-h)\lambda+hs_L\big)+(1-p)\beta\big((1-\tau-h)\lambda+hs_L\big)$

Therefore, $\left(\lambda_s^H,\lambda_s^L,\lambda_f^H,\lambda_f^L\right)=(\lambda-s_L,s_L,\lambda-s_L,s_L)$ must be the optimal solution when $\gamma<\frac{1-\omega}{\omega}\beta$.

Taken together the case when $\gamma \geq \frac{1-\omega}{\omega}\beta$ and the case when $\gamma<\frac{1-\omega}{\omega}\beta$, we show that the optimal solution to LP-2 is also optimal for LP-3, after allowing the budget constraints to be inequalities.

Proof of Proposition 1.4

Recall that Model 3 shows that the budget constraint is at equality because any unallocated capital cannot earn any return. This rationale applies in this model as well, so the proof below takes the budget constraint at equality.

Take any feasible allocation $(\lambda_{s,I}^H, \lambda_{s,I}^L, \lambda_{s,T}^H, \lambda_{s,T}^L, \lambda_f^H, \lambda_f^L)$, we first show that the allocation $(0, \lambda, \lambda_{s,T}^H, \lambda_{s,T}^L, \lambda_f^H, \lambda_f^L)$ is also feasible. One can verify that the left-hand side of inequalities (1) to (4) are increasing in $\lambda_{s,I}^L$ while the right-hand side does not depend on $\lambda_{s,I}^L$. Therefore, if $\lambda_{s,I}^L$ increases to λ, the left-hand side is greater while the right-hand remains unchanged, and thus still satisfies inequalities (1) to (4).

Furthermore, the feasible solution $(0, \lambda, \lambda_{s,T}^H, \lambda_{s,T}^L, \lambda_f^H, \lambda_f^L)$ produces a larger objective value than $(\lambda_{s,I}^H, \lambda_{s,I}^L, \lambda_{s,T}^H, \lambda_{s,T}^L, \lambda_f^H, \lambda_f^L)$, because the objective value is increasing in $\lambda_{s,I}^L$. Therefore, the optimal solution must have $\lambda_{s,I}^{H*} = 0$ and $\lambda_{s,I}^{L*} = \lambda$.

Next, let us solve for the feasible range for $\lambda_{s,T}^H$ and $\lambda_{s,T}^L$. Substitute $\lambda_{s,I}^{H*} = 0$ and $\lambda_{s,I}^{L*} = \lambda$ into inequalities (3) and (4). Solving (4) provides the following upper bound for $\lambda_{s,T}^L$:

$$\lambda_{s,T}^L \leq \frac{\omega(\beta+\gamma)\big((1-\tau-h)\lambda + h\lambda\big)}{\beta(1-\tau)} = \frac{\omega(\beta+\gamma)}{\beta}\lambda$$

Furthermore, by the budget constraint, we can substitute $\lambda_{s,T}^H = \lambda - \lambda_{s,T}^L$ into inequality (3) to solve for a lower bound for $\lambda_{s,T}^L$:

$$\lambda_{s,T}^L \geq \lambda - \frac{(1-\omega)(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau-h)}$$

Furthermore, the budget constraint requires that $0 \leq \lambda_{s,T}^L \leq \lambda$. Therefore, the range of $\lambda_{s,T}^L$ has a lower bound of $\max\left\{0, \lambda - \frac{(1-\omega)(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau-h)}\right\}$ and an upper bound of $\min\left\{\frac{\omega(\beta+\gamma)}{\beta}\lambda, \lambda\right\}$. This range for $\lambda_{s,T}^L$ is non-empty because first, it is clear that

$$\lambda - \frac{(1-\omega)(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau-h)} < \lambda$$

and second,

$$\lambda - \frac{(1-\omega)(\beta+\gamma)\big((1-\tau-h)\lambda + h\lambda\big)}{\beta(1-\tau-h)} < \frac{\omega(\beta+\gamma)}{\beta}\lambda$$

that is equivalent to showing

$$\frac{\omega(\beta+\gamma)}{\beta}\lambda - \left(\lambda - \frac{(1-\omega)(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau-h)}\right) = \frac{\gamma(1-\tau-\omega h) + \beta h(1-\omega)}{\beta(1-\tau-h)} > 0$$

Therefore, we obtain a feasible range for $\lambda_{s,T}^L$:

$$\max\left\{0, \lambda - \frac{(1-\omega)(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau-h)}\right\} \leq \lambda_{s,T}^L \leq \min\left\{\frac{\omega(\beta+\gamma)}{\beta}\lambda, \lambda\right\}$$

When $\gamma \geq \frac{1-\omega}{\omega}\beta$, $\frac{\omega(\beta+\gamma)}{\beta}\lambda \geq \lambda$, this range becomes

$$\max\left\{0, \lambda - \frac{(1-\omega)(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau-h)}\right\} \leq \lambda_{s,T}^L \leq \lambda$$

When $\gamma < \frac{1-\omega}{\omega}\beta$, $\frac{\omega(\beta+\gamma)}{\beta}\lambda < \lambda$, this range becomes

$$\max\left\{0, \lambda - \frac{(1-\omega)(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau-h)}\right\} \leq \lambda_{s,T}^L \leq \frac{\omega(\beta+\gamma)}{\beta}\lambda$$

One can compute the feasible range for $\lambda_{s,T}^H$ by substituting $\lambda_{s,T}^L = \lambda - \lambda_{s,T}^H$. Because the objective function does not refer to $\lambda_{s,T}^H, \lambda_{s,T}^L$, the optimal solution can take any value of $\lambda_{s,T}^H, \lambda_{s,T}^L$ within the feasible range.

Finally, we solve for the optimal value for λ_f^H and λ_f^L. Substitute $\lambda_{s,I}^{H*} = 0$ and $\lambda_{s,I}^{L*} = \lambda$ into inequalities (1) and (2). Solving (2) provides the following upper bound for λ_f^L:

$$\lambda_f^L \leq \frac{\omega(\beta+\gamma)\big((1-\tau-h)\lambda + h\lambda\big)}{\beta(1-\tau)} = \frac{\omega(\beta+\gamma)}{\beta}\lambda$$

Furthermore, by the budget constraint, we can substitute $\lambda_f^H = \lambda - \lambda_f^L$ into inequality (1) to solve for a lower bound for λ_f^L:

$$\lambda_f^L \geq \lambda - \frac{(1-\omega)(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau-h)}$$

Furthermore, the budget constraint requires that $0 \le \lambda_f^L \le \lambda$. Therefore, the range of λ_f^L has a lower bound of $\max\left\{0, \lambda - \frac{(1-\omega)(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau-h)}\right\}$ and an upper bound of $\min\left\{\frac{\omega(\beta+\gamma)}{\beta}\lambda, \lambda\right\}$. This range is non-empty, because first, it is clear that

$$\lambda - \frac{(1-\omega)(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau-h)} < \lambda$$

and second,

$$\lambda - \frac{(1-\omega)(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau-h)} < \frac{\omega(\beta+\gamma)}{\beta}\lambda$$

that is equivalent to showing

$$\frac{\omega(\beta+\gamma)}{\beta}\lambda - \left(\lambda - \frac{(1-\omega)(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau-h)}\right) = \frac{\gamma(1-\tau-\omega h) + \beta h(1-\omega)}{\beta(1-\tau-h)} > 0$$

Therefore, the feasible range of λ_f^L is:

$$\max\left\{0, \lambda - \frac{(1-\omega)(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau-h)}\right\} \le \lambda_f^L \le \min\left\{\frac{\omega(\beta+\gamma)}{\beta}\lambda, \lambda\right\}$$

Now, because the objective value is increasing in λ_f^L, the optimal solution λ_f^{L*} must take the upper bound.

$$\lambda_f^{L*} = \min\left\{\frac{\omega(\beta+\gamma)}{\beta}\lambda, \lambda\right\}$$

When $\gamma \ge \frac{1-\omega}{\omega}\beta$, $\frac{\omega(\beta+\gamma)}{\beta}\lambda \ge \lambda$, we have $\lambda_f^{L*} = \lambda$ and $\lambda_f^{H*} = 0$, and the optimal solution is $\left(\lambda_{s,I}^{H*}, \lambda_{s,I}^{L*}, \lambda_{s,T}^{H*}, \lambda_{s,T}^{L*}, \lambda_f^{H*}, \lambda_f^{L*}\right) = \left(0, \lambda, \lambda_{s,T}^{H*}, \lambda_{s,T}^{L*}, 0, \lambda\right)$, where $\lambda_{s,T}^{H*}$ and $\lambda_{s,T}^{L*}$ can take any value within the feasible range. Note that this corresponds to the first best scenario in the previous models.

When $\gamma < \frac{1-\omega}{\omega}\beta$, $\frac{\omega(\beta+\gamma)}{\beta}\lambda < \lambda$, we have $\lambda_f^{L*} = \frac{\omega(\beta+\gamma)}{\beta}\lambda$ and $\lambda_f^{H*} = \lambda - \frac{\omega(\beta+\gamma)}{\beta}\lambda$, and the optimal solution is $\left(\lambda_{s,I}^{H*}, \lambda_{s,I}^{L*}, \lambda_{s,T}^{H*}, \lambda_{s,T}^{L*}, \lambda_f^{H*}, \lambda_f^{L*}\right) = \left(0, \lambda, \lambda_{s,T}^{H*}, \lambda_{s,T}^{L*}, \lambda - \frac{\omega(\beta+\gamma)}{\beta}\lambda, \frac{\omega(\beta+\gamma)}{\beta}\lambda\right)$, where $\lambda_{s,T}^{H*}$

and $\lambda_{s,T}^{L*}$ can take any value within the feasible range. Note that the tax minimizing allocation can be specified only for the success outcome but not for the failure outcome. Hence, this solution is not the first best solution.

Proof of Proposition 2.4

As with Proposition 2, after determining the optimal payoff for inducing collaboration on the innovative project, the headquarters compares it with the optimal payoff for not inducing it. This allows the headquarters to determine whether pursuing the innovative opportunity is worthwhile.

From the proof of Proposition 2, the optimal payoff for not inducing collaboration is $\beta(1-\tau)\lambda$.

The headquarters compares this payoff with the optimal payoff for inducing collaboration as given in the two cases of Proposition 1.4.

Case 1. $\gamma \geq \frac{1-\omega}{\omega}\beta$: the optimal allocation that induces collaboration is $\lambda_f^L = \lambda_{s,I}^L = \lambda$ and $\lambda_f^H = \lambda_{s,I}^H = 0$, and the optimal payoff associated is $p(\beta+\gamma)(1-\tau)\lambda + (1-p)\beta(1-\tau)\lambda$. Inducing collaboration in this case has a higher optimal payoff, as $p(\beta+\gamma)(1-\tau)\lambda + (1-p)\beta(1-\tau)\lambda > \beta(1-\tau)\lambda$, making it worthwhile.

Case 2. $\gamma < \frac{1-\omega}{\omega}\beta$: the optimal allocation that induces collaboration is

$$\left(\lambda_{s,I}^{H*}, \lambda_{s,I}^{L*}, \lambda_f^{H*}, \lambda_f^{L*}\right) = \left(0, \lambda, \lambda - \frac{\omega(\beta+\gamma)}{\beta}\lambda, \frac{\omega(\beta+\gamma)}{\beta}\lambda\right)$$

that results in an optimal expected payoff of

$$p(\beta+\gamma)(1-\tau)\lambda + (1-p)\beta\left((1-\tau-h)\left(\lambda - \frac{\omega(\beta+\gamma)}{\beta}\lambda\right) + (1-\tau)\frac{\omega(\beta+\gamma)}{\beta}\lambda\right)$$
$$= \Big(p(\beta+\gamma)(1-\tau) + (1-p)\big((1-\tau-h)\beta + h\omega(\beta+\gamma)\big)\Big)\lambda$$

The difference between this payoff and that for not inducing collaboration is

$$\Big(p(\beta+\gamma)(1-\tau) + (1-p)\big((1-\tau-h)\beta + h\omega(\beta+\gamma)\big)\Big)\lambda - \beta(1-\tau)\lambda$$
$$= \Big(\big(p(1-\tau) + \omega h(1-p)\big)\gamma - h\beta(1-\omega)(1-p)\Big)\lambda$$

This difference is positive if and only if

$$\big(p(1-\tau)+\omega h(1-p)\big)\gamma - h\beta(1-\omega)(1-p) > 0$$

that is equivalent to

$$\gamma > \frac{(1-\omega)(1-p)h}{p(1-\tau)+\omega h(1-p)}\beta$$

This lower bound of γ, together with the upper bound that defines case 2, produce a range for γ.

One can check that the range is non-empty by computing the following.

$$\frac{1-\omega}{\omega}\beta - \frac{(1-\omega)(1-p)h}{p(1-\tau)+\omega h(1-p)}\beta = \frac{p(1-\omega)(1-\tau)}{\omega\big(p(1-\tau)+\omega h(1-p)\big)}\beta > 0$$

Therefore, in case 2, inducing collaboration is worthwhile if and only if $\gamma > \frac{(1-\omega)(1-p)h}{p(1-\tau)+\omega h(1-p)}\beta$.

In summary, when $\gamma \geq \frac{1-\omega}{\omega}\beta$, the first best solution is obtained, and the headquarters induces collaboration with no additional tax cost. It maximizes tax savings by allocating $(\lambda_{s,I}^{H*}, \lambda_{s,I}^{L*}, \lambda_f^{H*}, \lambda_f^{L*}) = (0, \lambda, 0, \lambda)$.

When $\frac{(1-\omega)(1-p)h}{p(1-\tau)+\omega h(1-p)}\beta < \gamma < \frac{1-\omega}{\omega}\beta$, inducing collaboration has a tax cost, but its benefit outweighs the cost, and the optimal allocation induces collaboration at the lowest tax cost. Following proposition 1.2B, this optimal allocation is

$$(\lambda_{s,I}^{H*}, \lambda_{s,I}^{L*}, \lambda_f^{H*}, \lambda_f^{L*}) = \left(0, \lambda, \lambda - \frac{\omega(\beta+\gamma)}{\beta}\lambda, \frac{\omega(\beta+\gamma)}{\beta}\lambda\right)$$

Finally, when $\gamma < \frac{(1-\omega)(1-p)h}{p(1-\tau)+\omega h(1-p)}\beta$, inducing collaboration is not worthwhile, and the optimal allocation is $\lambda^{L*} = \lambda$ and $\lambda^{H*} = 0$. Note that this allocation does not refer to the prototype outcome, because the headquarters decides not to pursue the innovative opportunity.

Proof of Proposition 3

First, compare $\gamma_{induce-base} = \frac{(1-\omega)h}{1-\tau-(1-\omega)h}\beta$ with $\gamma_{induce-1} = \gamma_{induce-2} = \gamma_{induce-3} = \frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta$, and one can see that

$$\frac{(1-\omega)h}{1-\tau-(1-\omega)h}\beta-\frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta=\frac{(1-\omega)(1-p)(1-\tau-h)h}{(1-\tau-(1-\omega)h)(p(1-\tau-h)+\omega h)}\beta>0$$

Therefore, $\gamma_{induce-base}>\gamma_{induce-1}=\gamma_{induce-2}=\gamma_{induce-3}$.

Next, compare $\gamma_{induce-4}=\frac{(1-\omega)(1-p)h}{p(1-\tau)+\omega h(1-p)}\beta$ with $\gamma_{induce-1}=\gamma_{induce-2}=\gamma_{induce-3}$, and one can see that

$$\frac{(1-\omega)(1-p)h}{p(1-\tau)+\omega h(1-p)}\beta-\frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta$$
$$=\frac{(1-\omega)hp(p(1-\tau-h)+h)}{\big(p(1-\tau)+\omega h(1-p)\big)(p(1-\tau-h)+\omega h)}\beta>0$$

Therefore, $\gamma_{induce-4}>\gamma_{induce-1}=\gamma_{induce-2}=\gamma_{induce-3}$.

Finally, compare $\gamma_{induce-base}$ with $\gamma_{induce-4}$, and one can see that

$$\frac{(1-\omega)h}{1-\tau-(1-\omega)h}\beta-\frac{(1-\omega)(1-p)h}{p(1-\tau)+\omega h(1-p)}\beta$$
$$=-\frac{(1-\omega)h\big((2-2\tau-h)p-(1-\tau-h)\big)}{(1-\tau-(1-\omega)h)(p(1-\tau)+\omega h(1-p))}\beta$$

When $p>\frac{1-\tau-h}{2-2\tau-h}$, $(2-2\tau-h)p-(1-\tau-h)>0$, and the difference is negative, so we have $\gamma_{induce-4}>\gamma_{induce-base}$.

When $p<\frac{1-\tau-h}{2-2\tau-h}$, $(2-2\tau-h)p-(1-\tau-h)<0$, and the difference is positive, so we have $\gamma_{induce-base}>\gamma_{induce-4}$.

Proof of Proposition 4.1

One can refer to the proof of Proposition 1.2 to see that when $\gamma<\frac{1-\omega}{\omega}\beta$, solving inequalities (3) and (4) gives an upper bound of $\lambda_s^L\leq s_L$.

Rearranging inequality (2) shows that it is equivalent to

$$\omega(\beta+\gamma)\big((1-\tau-h)\lambda_s^H+(1-\tau)\lambda_s^L\big)\geq\beta(1-\tau)c_f^L \qquad (2')$$

The LHS of inequality (2′) is increasing in λ_s^L, and its maximum value within the feasible range of λ_s^L occurs at $\lambda_s^L = s_L$. In other words, within the feasible region, the LHS of inequality (2′) is bounded above by the following expression.

$$\omega(\beta+\gamma)\big((1-\tau-h)\lambda_s^H + (1-\tau)\lambda_s^L\big) = \omega(\beta+\gamma)\big((1-\tau-h)(\lambda - s_L) + (1-\tau)s_L\big)$$

This expression can be simplified by recalling that inequality (4) is binding when $\lambda_s^L = s_L$, so we have

$$\omega(\beta+\gamma)\big((1-\tau-h)(\lambda - s_L) + (1-\tau)s_L\big) = \beta(1-\tau)s_L$$

Now, when the subsidiary perceives that it will be allocated an amount higher than s_L after the prototype fails, $c_f^L > s_L$. However, the LHS of $(2') \leq \beta(1-\tau)s_L < \beta(1-\tau)c_f^L$, making inequality (2′) impossible to be satisfied. Therefore, the linear program LP-2-C is infeasible.

Proof of Proposition 4.2

Rearranging inequality (2) shows that it is equivalent to

$$\omega(\beta+\gamma)\left((1-\tau-h)\lambda_{s,I}^H + (1-\tau)\lambda_{s,I}^L\right) \geq \beta(1-\tau)c_f^L \qquad (2')$$

The LHS of inequality (2′) is increasing in $\lambda_{s,I}^L$, and its maximum value within the feasible range of $\lambda_{s,I}^L$ occurs at $\lambda_{s,I}^L = \lambda$. In other words, within the feasible region, the LHS of inequality (2′) is bounded above by $\omega(\beta+\gamma)(1-\tau)\lambda$. In other words,

$$\omega(\beta+\gamma)\left((1-\tau-h)\lambda_{s,I}^H + (1-\tau)\lambda_{s,I}^L\right) \leq \omega(\beta+\gamma)(1-\tau)\lambda$$

Now, when the low-tax subsidiary perceives that it will be allocated an amount higher than $\lambda_{s,I}^{L*} = \frac{\omega(\beta+\gamma)}{\beta}\lambda$ after the prototype fails, $c_f^L > \frac{\omega(\beta+\gamma)}{\beta}\lambda$, and one can show that the RHS of (2′)

$$\beta(1-\tau)c_f^L > \beta(1-\tau)\frac{\omega(\beta+\gamma)}{\beta}\lambda = \omega(\beta+\gamma)(1-\tau)\lambda$$

Taken together, the RHS of (2′) is strictly greater than $\omega(\beta+\gamma)(1-\tau)\lambda$, while the LHS is at most $\omega(\beta+\gamma)(1-\tau)\lambda$, and thus making inequality (2) impossible to be satisfied. Therefore, the linear program LP-4-C is infeasible.

Proof of Lemma 1

After the general tax rate reduction, the high tax subsidiary faces a tax rate of $\tau + k$, $k > 0$, so its tax rate is still higher than the low-tax subsidiary. One can apply Proposition 2 with the new tax rate $\tau + k$ for the low tax subsidiary to obtain the result of Lemma 1.

Proof of Proposition 5

Comparing the optimal allocation before (Proposition 2) and after (Lemma 1) the general rate reduction, we obtain the following cases. First, when $\gamma > \frac{1-\omega}{\omega}\beta$, the first best allocation can be achieved, both before and after the general rate reduction, and in this case, $\lambda_k^{H*} = \lambda^{H*} = 0$.

Second, one can show that the inducing threshold after the general rate reduction (in Lemma1) is smaller than that before the rate reduction (in Proposition 2) by computing the following.

$$\frac{(\omega)h}{1-\tau-(1-\omega)h}\beta - \frac{(1-\omega)k}{1-\tau-(1-\omega)k}\beta$$
$$= \frac{(1-\omega)(1-\tau)(h-k)\beta}{(1-\tau-(1-\omega)h)(1-\tau-(1-\omega)k)} > 0$$

Therefore, the inducing threshold decreases from $\frac{(1-\omega)h}{1-\tau-(1-\omega)h}\beta$ to $\frac{(1-\omega)k}{1-\tau-(1-\omega)k}\beta$ after the general rate reduction. This result in two sub-cases.

First, when $\gamma < \frac{(1-\omega)k}{1-\tau-(1-\omega)k}\beta$, inducing collaboration is not worthwhile before the tax cut and is still not worthwhile after the tax cut, and in this case, $\lambda_k^{H*} = \lambda^{H*} = 0$.

Second, when $\frac{(1-\omega)k}{1-\tau-(1-\omega)k}\beta < \gamma < \frac{(1-\omega)h}{1-\tau-(1-\omega)h}\beta$, inducing collaboration becomes worthwhile only after the tax cut, and in this case,

$$\lambda^{H*} = 0 < \lambda_k^{H*} = \lambda - s_{L,k}$$

In the final case, when $\frac{(1-\omega)h}{1-\tau-(1-\omega)h}\beta < \gamma < \frac{1-\omega}{\omega}\beta$, inducing collaboration is worthwhile both before and after the tax cut. The optimal allocations are: $\lambda^{H*} = \lambda - s_L$ and $\lambda_k^{H*} = \lambda - s_{L,k}$.

Comparing these two values, one sees that

$$\lambda^{H*} - \lambda_k^{H*} = s_{L,k} - s_L = \frac{\omega(\beta+\gamma)(1-\tau)(h-k)(\beta-\omega(\beta+\gamma))\lambda}{(\beta(1-\tau)-\omega(\beta+\gamma)k)(\beta(1-\tau)-\omega(\beta+\gamma)h)}$$

Now because $\gamma < \frac{1-\omega}{\omega}\beta$, we have $\beta > \omega(\beta+\gamma)$ and

$$\beta(1-\tau) - \omega(\beta+\gamma)k > \beta(1-\tau-k) > 0$$

$$\beta(1-\tau) - \omega(\beta+\gamma)h > \beta(1-\tau-h) > 0$$

Therefore, $\lambda^{H*} > \lambda_k^{H*}$.

Proof of Lemma 2

The specific rate reduction applies to the innovative project but not to the traditional one, so the problem can be reformulated with the following LP. Solving this LP gives the optimal allocation if the HQ chooses to induce collaboration.

(LP-Base-S)

$$\max_{\lambda_k^H, \lambda_k^L} \ (\beta+\gamma)\Big((1-\tau-k)\lambda_k^H + (1-\tau)\lambda_k^L\Big)$$

Subject to.

$$(1-\omega)(\beta+\gamma)\Big((1-\tau-k)\lambda_k^H + (1-\tau)\lambda_k^L\Big) \geq \beta(1-\tau-h)\lambda_k^H \qquad (1)$$

$$\omega(\beta+\gamma)\Big((1-\tau-k)\lambda_k^H + (1-\tau)\lambda_k^L\Big) \geq \beta(1-\tau)\lambda_k^L \qquad (2)$$

$$\lambda_k^H + \lambda_k^L = \lambda \qquad (3)$$

$$\lambda_k^H, \lambda_k^L \geq 0 \qquad (4)$$

From the budget constraint, we have $\lambda_k^H = \lambda - \lambda_k^L$, and substitute it into the objective function:

$$(\beta+\gamma)\Big((1-\tau-k)\lambda_k^H + (1-\tau)\lambda_k^L\Big) = (\beta+\gamma)\Big((1-\tau-k)(\lambda-\lambda_k^L) + (1-\tau)\lambda_k^L\Big)$$

$$= (\beta+\gamma)((1-\tau-k)\lambda + k\lambda_k^L)$$

One can see from this expression that the objective function is increasing in λ_k^L.

Next, substitute $\lambda_k^H = \lambda - \lambda_k^L$ into inequalities (1) and (2), and we have:

$$(1-\omega)(\beta+\gamma)\Big((1-\tau-k)(\lambda-\lambda_k^L)+(1-\tau)\lambda_k^L\Big) \geq \beta(1-\tau-h)(\lambda-\lambda_k^L) \qquad (1')$$

$$\omega(\beta+\gamma)\Big((1-\tau-k)(\lambda-\lambda_k^L)+(1-\tau)\lambda_k^L\Big) \geq \beta(1-\tau)\lambda_k^L \qquad (2')$$

Solving inequality $(1')$ provides a *lower bound* of λ_k^L:

$$\lambda_k^L \geq \frac{\beta(1-\tau-h)-(1-\omega)(\beta+\gamma)(1-\tau-k)}{(1-\omega)(\beta+\gamma)k+\beta(1-\tau-h)} \cdot \lambda$$

Rearranging inequality $(2')$, we have

$$\omega(\beta+\gamma)(1-\tau-k)\lambda \geq (\beta(1-\tau)-\omega(\beta+\gamma)k)\lambda_k^L \qquad (2'')$$

Case 1: when $\beta(1-\tau)-\omega(\beta+\gamma)k \leq 0$, we have $\gamma \geq \frac{\beta(1-\tau-\omega k)}{\omega k}$, and the right hand side of $(2'')$ is negative while the left hand side is positive. Therefore, constraint (2) is satisfied for any $\lambda_k^L$and does not impose an upper bound on λ_k^L. However, the budget constraint enforces that $0 \leq \lambda_k^L \leq \lambda$.

With γ being the upper bound and the expression obtained in $(1')$ being the lower bound, we obtain a feasible range for λ_k^L:

$$\max\left\{\frac{\beta(1-\tau-h)-(1-\omega)(\beta+\gamma)(1-\tau-k)}{(1-\omega)(\beta+\gamma)k+\beta(1-\tau-h)}\lambda, 0\right\} \leq \lambda_k^L \leq \lambda$$

We first verify that this range is non-empty by computing the following.

$$\lambda - \frac{\beta(1-\tau-h)-(1-\omega)(\beta+\gamma)(1-\tau-k)}{(1-\omega)(\beta+\gamma)k+\beta(1-\tau-h)}\lambda = \frac{(1-\omega)(1-\tau)(\beta+\gamma)\lambda}{(1-\omega)(\beta+\gamma)k+\beta(1-\tau-h)} > 0$$

This shows that the upper bound of this range is strictly larger than the lower bound, hence the range is non-empty.

Recall that the objective function is increasing in λ_k^L, so the optimal λ_k^L takes the upper bound. In other words, $\lambda_k^{L*} = \lambda$.

Case 2: when $\beta(1-\tau)-\omega(\beta+\gamma)k > 0$, we have $\gamma < \frac{\beta(1-\tau-\omega k)}{\omega k}$, so one can divide $\beta(1-\tau)-\omega(\beta+\gamma)k$ from both sides of $(2'')$ to derive an upper bound of λ_k^L.

$$\lambda_k^L \le \frac{\omega(\beta+\gamma)(1-\tau-k)}{\beta(1-\tau)-\omega(\beta+\gamma)k}\lambda$$

Denote $s_{L,k} = \frac{\omega(\beta+\gamma)(1-\tau-k)}{\beta(1-\tau)-\omega(\beta+\gamma)k}\lambda$, and note that (2) is binding when $\lambda_k^L = s_{L,k}$.

Together with the budget constraint, one obtains a feasible range of λ_k^L

$$\max\left\{\frac{\beta(1-\tau-h)-(1-\omega)(\beta+\gamma)(1-\tau-k)}{(1-\omega)(\beta+\gamma)k+\beta(1-\tau-h)}\lambda, 0\right\} \le \lambda_k^L \le \min\{s_{L,k}, \lambda\}$$

We first verify that this range is non-empty by first computing that

$$s_{L,k} - \frac{\beta(1-\tau-h)-(1-\omega)(\beta+\gamma)(1-\tau-k)}{(1-\omega)(\beta+\gamma)k+\beta(1-\tau-h)}\lambda$$
$$= \frac{\big(1-\tau-k-\omega(h-k)\big)\gamma+(1-\omega)(h-k)\beta}{\big(\beta(1-\tau)-\omega(\beta+\gamma)k\big)\big((1-\omega)(\beta+\gamma)k+\beta(1-\tau-h)\big)}\lambda$$

is positive. This is because $1-\tau-k-\omega(h-k) \ge 1-\tau-k-(h-k) = 1-\tau-h > 0$, so we know that this difference is positive. Furthermore,

$$s_{L,k} = \frac{\omega(\beta+\gamma)(1-\tau-k)}{\beta(1-\tau)-\omega(\beta+\gamma)k}\lambda > 0$$

because of the case 2 condition $\beta(1-\tau)-\omega(\beta+\gamma)h > 0$. Therefore, the range for λ_k^L is non-empty.

The upper bound of λ_k^L is min $\{s_{L,k}, \lambda\}$ and is the allocation that maximizes the tax savings while maintaining the *Time 4* incentive compatibility constraints, so the optimal λ_k^{L*} takes this upper bound.

Next, I derive the two subcases where $\min\{s_L, \lambda\} = s_L$ and where $\min\{s_L, \lambda\} = \lambda$ by computing the difference between λ and s_L:

$$\lambda - s_{L,k} = \frac{(1-\tau)\big((1-\omega)\beta-\omega\gamma\big)}{\beta(1-\tau)-\omega(\beta+\gamma)k}\lambda$$

Because $\beta(1-\tau)-\omega(\beta+\gamma)k > 0$ and $1-\tau > 0$, $\lambda - s_L$ has the same sign as $(1-\omega)\beta - \omega\gamma$.

Case 2.1: when $(1-\omega)\beta-\omega\gamma \le 0$, we have $\gamma \ge \frac{1-\omega}{\omega}\beta$, and in this case, $s_{L,k} \ge \lambda$, so $\lambda_k^{L*} = \min\{s_L, \lambda\} = \lambda$.

Case 2.2: when $(1-\omega)\beta-\omega\gamma > 0$, we have $\gamma < \frac{1-\omega}{\omega}\beta$, and in this case, $s_{L,k} < \lambda$, so $\lambda_k^{L*} = \min\{s_L, \lambda\} = s_L$.

In summary,

$$\lambda_k^{L*} = \begin{cases} \lambda, if\ \gamma \ge \dfrac{\beta(1-\tau-\omega k)}{\omega k} \\ \lambda, if\ \gamma < \dfrac{\beta(1-\tau-\omega k)}{\omega k}\ and\ \gamma \ge \dfrac{1-\omega}{\omega}\beta \\ s_{L,k}, if\ \ \gamma < \dfrac{\beta(1-\tau-\omega k)}{\omega k} and\ \gamma < \dfrac{1-\omega}{\omega}\beta \end{cases}$$

One can combine the two cases where $\lambda_s^{L*} = \lambda$ because

$$\frac{\beta(1-\tau-\omega k)}{\omega k} - \frac{1-\omega}{\omega}\beta = \frac{\beta(1-\tau-k)}{\omega k} > 0$$

And we have $\frac{\beta(1-\tau-\omega k)}{\omega k} > \frac{1-\omega}{\omega}\beta$. Therefore, λ_s^{L*} can be described with

$$\lambda_k^{L*} = \begin{cases} \lambda, if\ \ \gamma \ge \dfrac{1-\omega}{\omega}\beta \\ s_{L,k}, if\ \gamma < \dfrac{1-\omega}{\omega}\beta \end{cases}$$

After determining the optimal payoff for inducing collaboration on the innovative project, the headquarters compares it with the optimal payoff for not inducing it. This allows the headquarters to determine whether pursuing the innovative opportunity is worthwhile.

If the headquarters does not induce collaboration on the innovative project, the total payoff is:

$$\beta\Big((1-\tau-h)\lambda_k^H + (1-\tau)\lambda_k^L\Big) = \beta((1-\tau-h)\lambda + h\lambda_k^L).$$

Note that the total payoff increases in λ_k^L because higher value of λ_k^L yields a higher tax saving, so the headquarters optimally allocates all the capital to the low-tax subsidiary when it forgoes the innovative project. In other words, $\lambda_k^{L*} = \lambda$ and $\lambda_k^{H*} = 0$. The optimal payoff is thus $\beta(1-\tau)\lambda$. The headquarters then compares this payoff with the optimal payoff for inducing collaboration, as given by optimal objective value of (LP-Base-S).

Case 1. $\gamma \geq \frac{1-\omega}{\omega}\beta$: the optimal allocation that induces collaboration is $\lambda_k^{L*} = \lambda$ and $\lambda_k^{H*} = 0$, and the optimal payoff associated with this allocation is $(\beta+\gamma)(1-\tau)\lambda$. Inducing collaboration in this case has a higher optimal payoff, as $(\beta+\gamma)(1-\tau)\lambda > \beta(1-\tau)\lambda$, making it worthwhile.

Case 2. $\gamma < \frac{1-\omega}{\omega}\beta$: the optimal allocation that induces collaboration is $\lambda_k^{L*} = s_{L,k}$ and $\lambda_k^{H*} = \lambda - s_{L,k}$, and the optimal payoff associated with this allocation is

$$(\beta+\gamma)\left((1-\tau-k)(\lambda-s_{L,k}) + (1-\tau)s_{L,k}\right) = \frac{(1-\tau)(1-\tau-k)(\beta+\gamma)\lambda}{\beta(1-\tau)-\omega(\beta+\gamma)k}$$

The difference between this payoff and that for not inducing collaboration is:

$$(\beta+\gamma)\left((1-\tau-h)\left(\lambda-s_{L,k}\right) + (1-\tau)s_{L,k}\right) - \beta(1-\tau)\lambda$$
$$= \frac{\beta(1-\tau)((1-\tau-(1-\omega)k)\gamma - k\beta(1-\omega))}{\beta(1-\tau)-\omega(\beta+\gamma)k}\lambda$$

When $\gamma < \frac{1-\omega}{\omega}\beta$, we have $(1-\tau)-\omega(\beta+\gamma)h > 0$, and the difference is positive if and only if

$$(1-\tau-(1-\omega)k)\gamma - k\beta(1-\omega) > 0$$

that is equivalent to

$$\gamma > \frac{(1-\omega)k}{1-\tau-(1-\omega)k}\beta$$

This lower bound of γ together with the upper bound that defines case 2 produces a range for γ.

One can check that the range is non-empty by computing the following.

$$\frac{1-\omega}{\omega}\beta - \frac{(1-\omega)k}{1-\tau-(1-\omega)k}\cdot\beta = \frac{(1-\omega)(1-\tau-k)}{\omega(1-\tau-(1-\omega)k)}\beta > 0$$

Therefore, in case 2, inducing collaboration is worthwhile if and only if $\gamma > \frac{(1-\omega)k}{1-\tau-(1-\omega)k}\beta$.

In summary, when $\gamma \geq \frac{1-\omega}{\omega}\beta$, first-best is obtained, and the headquarters induces collaboration with no additional tax cost. It maximizes tax savings by allocating $\lambda_k^{L*} = \lambda$ and $\lambda_k^{H*} = 0$.

When $\frac{(1-\omega)k}{1-\tau-(1-\omega)k}\beta < \gamma < \frac{1-\omega}{\omega}\beta$, inducing collaboration has a tax cost, but its benefit outweighs the cost, and the optimal allocation induces collaboration at the lowest tax cost. The optimal allocation in this case is the optimal solution to (LP-Base-S), that is $\lambda_k^{L*} = s_{L,k}$ and $\lambda_k^{H*} = \lambda - s_{L,k}$.

Finally, when $\gamma < \frac{(1-\omega)k}{1-\tau-(1-\omega)k}\beta$, inducing collaboration is not worthwhile, and the optimal allocation is $\lambda_k^{L*} = \lambda$ and $\lambda_k^{H*} = 0$.

Proof of Proposition 6

Comparing the optimal allocation before (Proposition 2) and after (Lemma 2) the specific rate reduction, we obtain the following cases. First, when $\gamma > \frac{1-\omega}{\omega}\beta$, the first best allocation can be achieved, both before and after the general rate reduction, and in this case, $\lambda_k^{H*} = \lambda^{H*} = 0$.

Second, one can show that the inducing threshold after the specific rate reduction (in Lemma2) is smaller than that before rate reduction (in Proposition 2) by computing the following.

$$\frac{(1-\omega)h}{1-\tau-(1-\omega)h}\beta - \frac{(1-\omega)k}{1-\tau-(1-\omega)k}\beta = \frac{(1-\omega)(1-\tau)(h-k)\beta}{(1-\tau-(1-\omega)h)(1-\tau-(1-\omega)k)} > 0$$

Therefore, the inducing threshold decreases from $\frac{(1-\omega)h}{1-\tau-(1-\omega)h}\beta$ to $\frac{(1-\omega)k}{1-\tau-(1-\omega)k}\beta$ after the general tax rate reduction. This result in two sub-cases.

First, when $\gamma < \frac{(1-\omega)k}{1-\tau-(1-\omega)k}\beta$, inducing collaboration is not worthwhile before the tax cut and is still not worthwhile after the tax cut, and in this case, $\lambda_k^{H*} = \lambda^{H*} = 0$.

Second, when $\frac{(1-\omega)k}{1-\tau-(1-\omega)k}\beta < \gamma < \frac{(1-\omega)h}{1-\tau-(1-\omega)h}\beta$, inducing collaboration becomes worthwhile only after the tax cut, and in this case,

$$\lambda^{H*} = 0 < \lambda_k^{H*} = \lambda - s_{L,k}$$

In the final case, when $\frac{(1-\omega)h}{1-\tau-(1-\omega)h}\beta < \gamma < \frac{1-\omega}{\omega}\beta$, inducing collaboration is worthwhile both before and after the tax cut. The optimal allocations are: $\lambda^{H*} = \lambda - s_L$ and $\lambda_k^{H*} = \lambda - s_{L,k}$.

Comparing these two values, one sees that

$$\lambda^{H*} - \lambda_k^{H*} = s_{L,k} - s_L = \frac{\omega(\beta+\gamma)(1-\tau)(h-k)(\beta-\omega(\beta+\gamma))\lambda}{(\beta(1-\tau)-\omega(\beta+\gamma)k)(\beta(1-\tau)-\omega(\beta+\gamma)h)}$$

Now, because $\gamma < \frac{1-\omega}{\omega}\beta$, we have $\beta > \omega(\beta+\gamma)$ and

$$\beta(1-\tau)-\omega(\beta+\gamma)k > \beta(1-\tau-k) > 0$$

$$\beta(1-\tau)-\omega(\beta+\gamma)h > \beta(1-\tau-h) > 0$$

Therefore, $\lambda^{H*} > \lambda_k^{H*}$.

Proof of Lemma 1.1

After the general tax rate reduction, the high tax subsidiary faces a tax rate of $\tau + k$, $k > 0$, so its tax rate is still higher than the low-tax subsidiary. One can apply Proposition 2.1 with the new tax rate $\tau + k$ for the low-tax subsidiary to obtain the result of Lemma 1.1.

Proof of Proposition 5.1

Comparing the optimal allocation before (in Proposition 2.1) and after (Lemma 1.1) the general rate reduction, we obtain the following cases. First, when $\gamma > \frac{1-\omega}{\omega}\beta$, the first best allocation can be achieved, both before and after the general rate reduction, and in this case, $\lambda_k^{H*} = \lambda^{H*} = 0$.

Second, one can show that the inducing threshold after the general rate reduction (in Lemma1.1) is smaller than that before the rate reduction (in Proposition 2.1A) by computing the following.

$$\frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta - \frac{(1-\omega)k}{p(1-\tau-h)+\omega k}\beta$$

$$= \frac{p(1-\omega)(1-\tau)(h-k)\beta}{(p(1-\tau-h)+\omega h)(p(1-\tau-h)+\omega k)} > 0$$

Therefore, the inducing threshold decreases from $\frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta$ to $\frac{(1-\omega)k}{p(1-\tau-h)+\omega k}\beta$ after the general tax rate reduction. This result in two sub-cases.

First, when $\gamma < \frac{(1-\omega)k}{p(1-\tau-h)+\omega k}\beta$, inducing collaboration is not worthwhile before the tax cut, and is still not worthwhile after the tax cut, and in this case, $\lambda_k^{H*} = \lambda^{H*} = 0$.

Second, when $\frac{(1-\omega)k}{p(1-\tau-h)+\omega k}\beta < \gamma < \frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta$, inducing collaboration becomes worthwhile only after the tax cut, and in this case,

$$\lambda^{H*} = 0 < \lambda_k^{H*} = \lambda - s_{L,k}$$

In the final case, when $\frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta < \gamma < \frac{1-\omega}{\omega}\beta$, inducing collaboration is worthwhile both before and after the general rate reduction. The optimal allocations are: $\lambda^{H*} = \lambda - s_L$ and $\lambda_k^{H*} = \lambda - s_{L,k}$.

Comparing these two values, one sees that

$$\lambda^{H*} - \lambda_k^{H*} = s_{L,k} - s_L = \frac{\omega(\beta+\gamma)(1-\tau)(h-k)(\beta-\omega(\beta+\gamma))\lambda}{(\beta(1-\tau)-\omega(\beta+\gamma)k)(\beta(1-\tau)-\omega(\beta+\gamma)h)}$$

Now, because $\gamma < \frac{1-\omega}{\omega}\beta$, we have $\beta > \omega(\beta+\gamma)$ and

$$\beta(1-\tau) - \omega(\beta+\gamma)k > \beta(1-\tau-k) > 0$$

$$\beta(1-\tau) - \omega(\beta+\gamma)h > \beta(1-\tau-h) > 0$$

Therefore, $\lambda^{H*} > \lambda_k^{H*}$.

Proof of Lemma 1.2

After the general tax rate reduction, the high tax subsidiary faces a tax rate of $\tau + k$, $k > 0$, so its tax rate is still higher than the low-tax subsidiary. One can apply Proposition 2.2 with the new tax rate $\tau + k$ for the low-tax subsidiary to obtain the result of Lemma 1.2.

Proof of Proposition 5.2

Comparing the optimal allocation before (in Proposition 2.2) and after (Lemma 1.2) the general rate reduction, we obtain the following cases.

First, when $\gamma > \frac{1-\omega}{\omega}\beta$, the first best allocation can be achieved, both before and after the general rate reduction, and in this case, $\lambda_{s,k}^{H*} = \lambda_{f,k}^{H*} = \lambda_s^{H*} = \lambda_f^{H*} = 0$.

Second, one can show that the inducing threshold after the general rate reduction (in Lemma 1.2) is smaller than that before the rate reduction (in Proposition 2.2) by computing the following.

$$\frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta - \frac{(1-\omega)k}{p(1-\tau-h)+\omega k}\beta$$

$$= \frac{p(1-\omega)(1-\tau)(h-k)\beta}{(p(1-\tau-h)+\omega h)(p(1-\tau-h)+\omega k)} > 0$$

Therefore, the inducing threshold decreases from $\frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta$ to $\frac{(1-\omega)k}{p(1-\tau-h)+\omega k}\beta$ after the general tax rate reduction. This result in two sub-cases.

First, when $\gamma < \frac{(1-\omega)k}{p(1-\tau-h)+\omega k}\beta$, inducing collaboration is not worthwhile before the tax cut, and is still not worthwhile after the tax cut, and in this case, $\lambda_k^{H*} = \lambda^{H*} = 0$.

Second, when $\frac{(1-\omega)k}{p(1-\tau-h)+\omega k}\beta < \gamma < \frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta$ inducing collaboration becomes worthwhile only after the tax cut, and in this case,

$$\lambda^{H*} = 0 < \lambda_{s,k}^{H*} = \lambda_{f,k}^{H*} = \lambda - s_{L,k}$$

In the final case, when $\frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta < \gamma < \frac{1-\omega}{\omega}\beta$, inducing collaboration is worthwhile both before and after the general rate reduction. The respective optimal allocations are: $\lambda_s^{H*} = \lambda_f^{H*} = \lambda - s_L$ and $\lambda_{s,k}^{H*} = \lambda_{f,k}^{H*} = \lambda - s_{L,k}$.

Comparing these two values, one sees that

$$\lambda^{H*} - \lambda_k^{H*} = s_{L,k} - s_L = \frac{\omega(\beta+\gamma)(1-\tau)(h-k)(\beta-\omega(\beta+\gamma))\lambda}{(\beta(1-\tau)-\omega(\beta+\gamma)k)(\beta(1-\tau)-\omega(\beta+\gamma)h)}$$

Now, because $\gamma < \frac{1-\omega}{\omega}\beta$, we have $\beta > \omega(\beta+\gamma)$ and

$$\beta(1-\tau) - \omega(\beta+\gamma)k > \beta(1-\tau-k) > 0$$

$$\beta(1-\tau) - \omega(\beta+\gamma)h > \beta(1-\tau-h) > 0$$

Therefore, $\lambda_s^{H*} > \lambda_{s,k}^{H*}$ and $\lambda_f^{H*} > \lambda_{f,k}^{H*}$.

Proof of Lemma 1.4

After the general tax rate reduction, the high tax subsidiary faces a tax rate of $\tau + k$, $k > 0$, so its tax rate is still higher than the low-tax subsidiary. One can apply Proposition 2.4 with the new tax rate $\tau + k$ for the low-tax subsidiary to obtain the result of Lemma 1.4.

Proof of Proposition 5.4

Comparing the optimal allocation before (Proposition 2.4) and after (Lemma 1.4) the general rate reduction, we obtain the following cases.

First, when $\gamma > \frac{1-\omega}{\omega}\beta$, the first best allocation can be achieved, both before and after the general rate reduction, and in this case, $\lambda_{s,I,k}^{H*} = \lambda_{f,k}^{H*} = \lambda_{s,I}^{H*} = \lambda_f^{H*} = 0$.

Second, one can show that the inducing threshold after the general rate reduction (in Lemma 1.4) is smaller than that before the rate reduction (in Proposition 2.4) by computing the following.

$$\frac{(1-p)(1-\omega)h}{p(1-\tau-\omega h)+\omega h}\beta - \frac{(1-p)(1-\omega)k}{p(1-\tau-\omega k)+\omega k}\beta$$

$$= \frac{p(1-p)(1-\omega)(1-\tau)(h-k)\beta}{(p(1-\tau-\omega h)+\omega h)(p(1-\tau-\omega k)+\omega k)} > 0$$

Therefore, the inducing threshold decreases from $\frac{(1-p)(1-\omega)h}{p(1-\tau-\omega h)+\omega h}\beta$ to $\frac{(1-p)(1-\omega)k}{p(1-\tau-\omega k)+\omega k}\beta$ after the general tax rate reduction. This result in two sub-cases.

First, when $\gamma < \frac{(1-p)(1-\omega)k}{p(1-\tau-\omega k)+\omega k}\beta$, inducing collaboration is not worthwhile before the tax cut, and is still not worthwhile after the tax cut, and in this case, $\lambda_k^{H*} = \lambda^{H*} = 0$.

Second, when $\frac{(1-p)(1-\omega)k}{p(1-\tau-\omega k)+\omega k}\beta < \gamma < \frac{(1-p)(1-\omega)h}{p(1-\tau-\omega h)+\omega h}\beta$, inducing collaboration becomes worthwhile only after the tax cut, and the optimal allocations are:

$\lambda_{f,k}^{H*} = \lambda - \frac{\omega(\beta+\gamma)}{\beta}\lambda > 0 = \lambda^{H*}$, an increase in allocation for the failure outcome, and $\lambda_{s,I,k}^{H*} = \lambda^{H*} = 0$, no change for the success outcome.

In the final case, when $\frac{(1-p)(1-\omega)h}{p(1-\tau-\omega h)+\omega h}\beta < \gamma$, inducing collaboration is worthwhile both before and after the tax cut, and when $\gamma < \frac{1-\omega}{\omega}\beta$, we have

$$\lambda_{f,k}^{H*} = \lambda - \frac{\omega(\beta+\gamma)}{\beta}\lambda = \lambda_f^{H*}, \qquad \lambda_{s,I,k}^{H*} = 0 = \lambda_{s,I}^{H*}$$

and $\lambda_{f,k}^{H*} = \lambda_f^{H*}$ and $\lambda_{s,I,k}^{H*} = \lambda_{s,I}^{H*}$.

Proof of Lemma 2.1

The specific rate reduction applies to the innovative project but not to the traditional one, so the problem can be reformulated with LP-1-S. Solving this LP gives the optimal allocation if the HQ chooses to induce collaboration.

(LP-1-S)

$$\max_{\lambda_k^H,\lambda_k^L} \; p(\beta+\gamma)\Big((1-\tau-k)\lambda_k^H + (1-\tau)\lambda_k^L\Big) + (1-p)\beta\Big((1-\tau-h)\lambda_k^H + (1-\tau)\lambda_k^L\Big)$$

Subject to.

$$p(1-\omega)(\beta+\gamma)\Big((1-\tau-k)\lambda_k^H + (1-\tau)\lambda_k^L\Big) + (1-p)\beta(1-\tau-h)\lambda_k^H \geq \beta(1-\tau-h)\lambda_k^H \qquad (1)$$

$$p\omega(\beta+\gamma)\Big((1-\tau-k)\lambda_k^H + (1-\tau)\lambda_k^L\Big) + (1-p)\beta(1-\tau)\lambda_k^L \geq \beta(1-\tau)\lambda_k^L \qquad (2)$$

$$(1-\omega)(\beta+\gamma)\Big((1-\tau-k)\lambda_k^H + (1-\tau)\lambda_k^L\Big) \geq \beta(1-\tau-h)\lambda_k^H \qquad (3)$$

$$\omega(\beta+\gamma)\Big((1-\tau-k)\lambda_k^H + (1-\tau)\lambda_k^L\Big) \geq \beta(1-\tau)\lambda_k^L \qquad (4)$$

$$\lambda_k^H + \lambda_k^L = \lambda \qquad (5)$$

$$\lambda_k^H, \lambda_k^L \geq 0 \qquad (6)$$

From the budget constraint, $\lambda_k^H = \lambda - \lambda_k^L$, and substitute this expression into the objective function:

$$p(\beta+\gamma)\Big((1-\tau-k)\lambda_k^H + (1-\tau)\lambda_k^L\Big) + (1-p)\beta\Big((1-\tau-h)\lambda_k^H + (1-\tau)\lambda_k^L\Big)$$

$$= p(\beta+\gamma)\Big((1-\tau-k)(\lambda-\lambda_k^L)+(1-\tau)\lambda_k^L\Big)$$
$$+ (1-p)\beta\Big((1-\tau-h)(\lambda-\lambda_k^L)+(1-\tau)\lambda_k^L\Big)$$

$$= p(\beta+\gamma)\Big((1-\tau-k)\lambda+k\lambda_k^L\Big)+(1-p)\beta\Big((1-\tau-h)\lambda+h\lambda_k^L\Big)$$

One can see from this expression that the objective function is increasing in λ_k^L. Therefore, the optimal objective value is obtained at the upper bound of λ_k^L.

Rearranging inequalities (1) and (2) obtains

$$(1-\omega)(\beta+\gamma)\Big((1-\tau-k)(\lambda-\lambda_k^L)+(1-\tau)\lambda_k^L\Big)\geq\beta(1-\tau-h)(\lambda-\lambda_k^L)\qquad(1')$$

$$\omega(\beta+\gamma)\Big((1-\tau-k)(\lambda-\lambda_k^L)+(1-\tau)\lambda_k^L\Big)\geq\beta(1-\tau)\lambda_k^L\qquad(2')$$

Notice that these are equivalent to inequalities (3) and (4). Therefore, the inequalities (1) and (2) are redundant, and the feasible set can be solely described by inequalities (3) – (6). Comparing this with (LP-Base-S), they have the same set of constraints and thus have the same feasible range for λ_k^L. Therefore, the optimal allocation λ_k^{L*} to (LP-1-S) is the same as the optimal solution to (LP-Base-S):

$$\lambda_k^{L*}=\begin{cases}\lambda, if\ \ \gamma\geq\dfrac{1-\omega}{\omega}\beta\\ s_{L,k}, if\ \gamma<\dfrac{1-\omega}{\omega}\beta\end{cases}$$

Here,

$$s_{L,k}=\frac{\omega(\beta+\gamma)(1-\tau-k)}{\beta(1-\tau)-\omega(\beta+\gamma)k}\ \lambda$$

After determining the optimal payoff for inducing collaboration on the innovative project, the headquarters compares it with the optimal payoff for not inducing it. This allows the headquarters to determine whether pursuing the innovative opportunity is worthwhile.

If the headquarters does not induce collaboration on the innovative project, the total payoff is:

$$\beta\Big((1-\tau-h)\lambda_k^H+(1-\tau)\lambda_k^L\Big)=\beta((1-\tau-h)\lambda+h\lambda_k^L).$$

Note that the total payoff increases in λ_k^L because higher value of λ_k^L yields a higher tax saving, so the headquarters optimally allocates all the capital to the low-tax subsidiary when it forgoes the innovative project. In other words, $\lambda_k^{L*} = \lambda$ and $\lambda_k^{H*} = 0$. The optimal payoff is thus $\beta(1 - \tau)\lambda$. The headquarters then compares this payoff with the optimal payoff for inducing collaboration, as given by optimal objective value of (LP-1-S).

Case 1. $\gamma \geq \frac{1-\omega}{\omega}\beta$: the optimal allocation that induces collaboration is $\lambda_k^{L*} = \lambda$ and $\lambda_k^{H*} = 0$, and the optimal expected payoff associated with this allocation is $p(\beta + \gamma)(1 - \tau)\lambda + (1 - p)\beta(1 - \tau)\lambda$. Inducing collaboration in this case has a higher optimal payoff, as $p(\beta + \gamma)(1 - \tau)\lambda + (1 - p)\beta(1 - \tau)\lambda > \beta(1 - \tau)\lambda$, making it worthwhile.

Case 2. $\gamma < \frac{1-\omega}{\omega}\beta$: the optimal allocation that induces collaboration is $\lambda_k^{L*} = s_{L,k}$ and $\lambda_k^{H*} = \lambda - s_{L,k}$, and the optimal expected payoff associated with this allocation is

$$p(\beta + \gamma)\Big((1 - \tau - k)(\lambda - s_{L,k}) + (1 - \tau)s_{L,k}\Big) + (1 - p)\beta\Big((1 - \tau - h)(\lambda - s_{L,k}) + (1 - \tau)s_{L,k}\Big)$$

$$= \frac{(1 - \tau)\Big(\big((1 - \tau - k)p + \omega(1 - p)(h - k)\big)\gamma + (1 - \tau - h + (h - k)(p + \omega(1 - p)))\beta\Big)\beta\lambda}{\beta(1 - \tau) - \omega(\beta + \gamma)k}$$

The difference between this payoff and that for not inducing collaboration is:

$$\frac{(1 - \tau)\Big(\big((1 - \tau - k)p + \omega(1 - p)(h - k)\big)\gamma + (1 - \tau - h + (h - k)(p + \omega(1 - p)))\beta\Big)\beta\lambda}{\beta(1 - \tau) - \omega(\beta + \gamma)k} - \beta(1 - \tau)\lambda$$

$$= \frac{\beta(1 - \tau)\Big(\Big(p(1 - \tau - k) + \omega\big(h - p(h - k)\big)\Big)\gamma - \beta(1 - \omega)\big(h - p(h - k)\big)\Big)}{\beta(1 - \tau) - \omega(\beta + \gamma)k}\lambda$$

When $\gamma < \frac{1-\omega}{\omega}\beta$, $(1 - \tau) - \omega(\beta + \gamma)h > 0$, and the difference is positive if and only if

$$\Big(p(1 - \tau - k) + \omega\big(h - p(h - k)\big)\Big)\gamma - \beta(1 - \omega)\big(h - p(h - k)\big) > 0$$

that is equivalent to

$$\gamma > \frac{(1-\omega)(h-p(h-k))}{p(1-\tau-k)+\omega\big(h-p(h-k)\big)}\beta$$

This lower bound of γ together with the upper bound that defines case 2 produces a range for γ.

One can check that the range is non-empty by computing the following.

$$\frac{1-\omega}{\omega}\beta - \frac{(1-\omega)(h-p(h-k))}{p(1-\tau-k)+\omega\big(h-p(h-k)\big)}\beta = \frac{p(1-\omega)(1-\tau-k)}{\omega\Big(p(1-\tau-k)+\omega\big(h-p(h-k)\big)\Big)}\beta > 0$$

Therefore, in case 2, inducing collaboration is worthwhile if and only if when $\gamma > \frac{(1-\omega)(h-p(h-k))}{p(1-\tau-k)+\omega(h-p(h-k))}\beta$.

In summary, when $\gamma \geq \frac{1-\omega}{\omega}\beta$, first-best is obtained, and the headquarters induces collaboration with no additional tax cost. It maximizes tax savings by allocating $\lambda_k^{L*} = \lambda$ and $\lambda_k^{H*} = 0$.

When $\frac{(1-\omega)(h-p(h-k))}{p(1-\tau-k)+\omega(h-p(h-k))}\beta < \gamma < \frac{1-\omega}{\omega}\beta$, inducing collaboration has a tax cost, but its benefit outweighs the cost, and the optimal allocation induces collaboration at the lowest tax cost. The optimal allocation in this case is the optimal solution to (LP-1-S), that is $\lambda_k^{L*} = s_{L,k}$ and $\lambda_k^{H*} = \lambda - s_{L,k}$.

Finally, when $\gamma < \frac{(1-\omega)(h-p(h-k))}{p(1-\tau-k)+\omega(h-p(h-k))}\beta$, inducing collaboration is not worthwhile, and the optimal allocation is $\lambda_k^{L*} = \lambda$ and $\lambda_k^{H*} = 0$.

Proof of Proposition 6.1

Comparing the optimal allocation before (Proposition 2.1) and after (Lemma 2.1) the specific rate reduction, we obtain the following cases. First, when $\gamma > \frac{1-\omega}{\omega}\beta$, the first best allocation can be achieved, both before and after the general rate reduction, and in this case, $\lambda_k^{H*} = \lambda^{H*} = 0$.

Second, one can show that the inducing threshold after the specific rate reduction (in Lemma 2.1) is smaller than that before rate reduction (in Proposition 2.1) by computing the following.

$$\frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta - \frac{(1-\omega)(h-p(h-k))}{p(1-\tau-k)+\omega\big(h-p(h-k)\big)}\beta$$
$$= \frac{(p(1-\tau-h)+h)(1-\omega)(h-k)\beta}{\Big(p(1-\tau-k)+\omega\big(h-p(h-k)\big)\Big)(p(1-\tau-h)+\omega h)} > 0$$

Therefore, the inducing threshold decreases from $\frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta$ to $\frac{(1-\omega)(h-p(h-k))}{p(1-\tau-k)+\omega\left(h-p(h-k)\right)}\beta$ after the specific tax rate reduction. This results in two subcases.

First, when $\gamma < \frac{(1-\omega)(h-p(h-k))}{p(1-\tau-k)+\omega\left(h-p(h-k)\right)}\beta$, inducing collaboration is not worthwhile before the tax cut and is still not worthwhile after the tax cut, and in this case, $\lambda_k^{H*} = \lambda^{H*} = 0$.

Second, when $\frac{(1-\omega)(h-p(h-k))}{p(1-\tau-k)+\omega\left(h-p(h-k)\right)}\beta < \gamma < \frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta$, inducing collaboration becomes worthwhile only after the tax cut, and in this case,

$$\lambda^{H*} = 0 < \lambda_k^{H*} = \lambda - s_{L,k}$$

In the final case, when $\frac{(1-\omega)h}{p(1-\tau-k)+\omega h}\beta < \gamma < \frac{1-\omega}{\omega}\beta$, inducing collaboration is worthwhile both before and after the tax cut. The optimal allocations are: $\lambda^{H*} = \lambda - s_L$ and $\lambda_k^{H*} = \lambda - s_{L,k}$.

Comparing these two values, one sees that

$$\lambda^{H*} - \lambda_k^{H*} = s_{L,k} - s_L = \frac{\omega(\beta+\gamma)(1-\tau)(h-k)(\beta-\omega(\beta+\gamma))\lambda}{(\beta(1-\tau)-\omega(\beta+\gamma)k)(\beta(1-\tau)-\omega(\beta+\gamma)h)}$$

Now, because $\gamma < \frac{1-\omega}{\omega}\beta$, we have $\beta > \omega(\beta+\gamma)$ and

$$\beta(1-\tau) - \omega(\beta+\gamma)k > \beta(1-\tau-k) > 0$$

$$\beta(1-\tau) - \omega(\beta+\gamma)h > \beta(1-\tau-h) > 0$$

Therefore, $\lambda^{H*} > \lambda_k^{H*}$.

Proof of Lemma 2.2

The specific rate reduction applies to the innovative project but not to the traditional one, so the problem can be reformulated with LP-2-S. Solving this LP gives the optimal allocation if the HQ chooses to induce collaboration.

(LP-2-S)

$$\max_{\lambda^H_{s,k},\lambda^L_{s,k},\lambda^H_{f,k},\lambda^L_{f,k}} p(\beta+\gamma)\left((1-\tau-k)\lambda^H_{s,k}+(1-\tau)\lambda^L_{s,k}\right)$$

$$+(1-p)\beta\left((1-\tau-h)\lambda^H_{f,k}+(1-\tau)\lambda^L_{f,k}\right)$$

Subject to.

$$p(1-\omega)(\beta+\gamma)\left((1-\tau-k)\lambda^H_{s,k}+(1-\tau)\lambda^L_{s,k}\right)+(1-p)\beta(1-\tau-h)\lambda^H_{f,k}$$

$$\geq \beta(1-\tau-h)\lambda^H_{f,k} \qquad (1)$$

$$p\omega(\beta+\gamma)\left((1-\tau-k)\lambda^H_{s,k}+(1-\tau)\lambda^L_{s,k}\right)+(1-p)\beta(1-\tau)\lambda^L_{f,k} \geq \beta(1-\tau)\lambda^L_{f,k} \qquad (2)$$

$$(1-\omega)(\beta+\gamma)\left((1-\tau-k)\lambda^H_{s,k}+(1-\tau)\lambda^L_{s,k}\right)\geq \beta(1-\tau-h)\lambda^H_{s,k} \qquad (3)$$

$$\omega(\beta+\gamma)\left((1-\tau-k)\lambda^H_{s,k}+(1-\tau)\lambda^L_{s,k}\right)\geq \beta(1-\tau)\lambda^L_{s,k} \qquad (4)$$

$$\lambda^H_{s,k}+\lambda^L_{s,k}=\lambda \qquad (5)$$

$$\lambda^H_{f,k}+\lambda^L_{f,k}=\lambda \qquad (6)$$

$$\lambda^H_{s,k},\lambda^L_{s,k},\lambda^H_{f,k},\lambda^L_{f,k}\geq 0 \qquad (7)$$

Let us begin with computing $\lambda^{L*}_{s,k}$ and $\lambda^{H*}_{s,k}$.

Substitute $\lambda^H_{s,k}=\lambda-\lambda^L_{s,k}$ into (3) and (4), and we obtain

$$(1-\omega)(\beta+\gamma)\left((1-\tau-k)(\lambda-\lambda^L_{s,k})+(1-\tau)\lambda^L_{s,k}\right)\geq \beta(1-\tau-h)(\lambda-\lambda^L_{s,k}) \qquad (3')$$

$$\omega(\beta+\gamma)\left((1-\tau-k)(\lambda-\lambda^L_{s,k})+(1-\tau)\lambda^L_{s,k}\right)\geq \beta(1-\tau)\lambda^L_{s,k} \qquad (4')$$

Solving $(3')$ derives a lower bound of $\lambda^L_{s,k}$:

$$\lambda^L_{s,k}\geq \frac{\beta(1-\tau-h)-(1-\omega)(\beta+\gamma)(1-\tau-k)}{(1-\omega)(\beta+\gamma)k+\beta(1-\tau-h)}\lambda$$

Rearranging $(4')$ by moving all the terms of $\lambda^L_{s,k}$ to the RHS

$$\omega(\beta+\gamma)(1-\tau-k)\lambda\geq (\beta(1-\tau)-\omega(\beta+\gamma)k)\lambda^L_{s,k} \qquad (4'')$$

Case 1: when $\beta(1-\tau)-\omega(\beta+\gamma)k\leq 0$, we have $\gamma\geq\frac{\beta(1-\tau-\omega k)}{\omega k}$, and the right hand side of $(4'')$ is negative while the left hand side is positive. Therefore, constraint (4) is satisfied for any $\lambda^L_{s,k}$ and does not impose an upper bound on $\lambda^L_{s,k}$. However, the budget constraint enforces that $0\leq\lambda^L_{s,k}\leq\lambda$.

Together with $(3')$, we obtain the following range for λ_s^L.

$$\max\left\{\frac{\beta(1-\tau-h)-(1-\omega)(\beta+\gamma)(1-\tau-k)}{(1-\omega)(\beta+\gamma)k+\beta(1-\tau-h)}\lambda, 0\right\} \le \lambda_{s,k}^L \le \lambda$$

We first verify that this range is non-empty by computing that

$$\lambda - \frac{\beta(1-\tau-h)-(1-\omega)(\beta+\gamma)(1-\tau-k)}{(1-\omega)(\beta+\gamma)k+\beta(1-\tau-h)}\lambda = \frac{(1-\omega)(1-\tau)(\beta+\gamma)}{(1-\omega)(\beta+\gamma)k+\beta(1-\tau-h)}\lambda > 0$$

This shows that the upper bound of this range is strictly larger than the lower bound, hence the range is non-empty. Therefore, the optimal $\lambda_{s,k}^{L*}$ takes the upper bound value $\lambda_{s,k}^{L*} = \lambda$.

Case 2: when $\beta(1-\tau)-\omega(\beta+\gamma)k > 0$, we have $\gamma < \frac{\beta(1-\tau-\omega k)}{\omega k}$, so one can divide $\beta(1-\tau)-\omega(\beta+\gamma)k$ from both sides of $(4')$ to derive an upper bound of $\lambda_{s,k}^L$.

$$\lambda_{s,k}^L \le \frac{\omega(\beta+\gamma)(1-\tau-k)}{\beta(1-\tau)-\omega(\beta+\gamma)k}\lambda$$

Denote $s_{L,k} = \frac{\omega(\beta+\gamma)(1-\tau-k)}{\beta(1-\tau)-\omega(\beta+\gamma)k}\lambda$, and note that (4) is binding when $\lambda_{s,k}^L = s_{L,k}$. Together with the budget constraint, one obtains a range of $\lambda_{s,k}^L$

$$\max\left\{\frac{\beta(1-\tau-h)-(1-\omega)(\beta+\gamma)(1-\tau-k)}{(1-\omega)(\beta+\gamma)k+\beta(1-\tau-h)}\lambda, 0\right\} \le \lambda_{s,k}^L \le \min\{s_{L,k}, \lambda\}$$

Let us first verify that this range is non-empty by computing that

$$s_{L,k} - \frac{\beta(1-\tau-h)-(1-\omega)(\beta+\gamma)(1-\tau-k)}{(1-\omega)(\beta+\gamma)k+\beta(1-\tau-h)}\lambda$$
$$= \frac{\big(1-\tau-k-\omega(h-k)\big)\gamma+(1-\omega)(h-k)\beta}{\big(\beta(1-\tau)-\omega(\beta+\gamma)k\big)\big((1-\omega)(\beta+\gamma)k+\beta(1-\tau-h)\big)}\lambda$$

is positive. This is because $1-\tau-k-\omega(h-k) \ge 1-\tau-k-(h-k) = 1-\tau-h > 0$, so we know that this difference is positive. Furthermore,

$$s_{L,k} = \frac{\omega(\beta+\gamma)(1-\tau-k)}{\beta(1-\tau)-\omega(\beta+\gamma)k}\lambda > 0$$

because of the case-2 condition $\beta(1-\tau)-\omega(\beta+\gamma)h > 0$. Therefore, the range for $\lambda_{s,k}^L$ is non-empty.

The upper bound of min $\{s_{L,k}, \lambda\}$ for $\lambda_{s,k}^{L}$ is the allocation that maximizes the tax savings while maintaining the *Time 4* incentive compatibility constraints, so the optimal $\lambda_{s,k}^{L*}$ takes this upper bound.

Next, I derive the two subcases where $\min\{s_{L,k}, \lambda\} = s_{L,k}$ and where $\min\{s_{L,k}, \lambda\} = \lambda$ by computing the difference between λ and $s_{L,k}$:

$$\lambda - s_{L,k} = \frac{(1-\tau)\big((1-\omega)\beta - \omega\gamma\big)}{\beta(1-\tau) - \omega(\beta+\gamma)k}\lambda$$

Because $\beta(1-\tau) - \omega(\beta+\gamma)k > 0$ and $1-\tau > 0$, $\lambda - s_L$ has the same sign as $(1-\omega)\beta - \omega\gamma$.

Case 2.1: when $(1-\omega)\beta - \omega\gamma \leq 0$, we have $\gamma \geq \frac{1-\omega}{\omega}\beta$, and in this case, $s_{L,k} \geq \lambda$, so $\lambda_{s,k}^{L*} = \min\{s_{L,k}, \lambda\} = \lambda$.

Case 2.2: when $(1-\omega)\beta - \omega\gamma > 0$, we have $\gamma < \frac{1-\omega}{\omega}\beta$, and in this case, $s_{L,k} < \lambda$, so $\lambda_{s,k}^{L*} = \min\{s_{L,k}, \lambda\} = s_{L,k}$.

In summary,

$$\lambda_{s,k}^{L*} = \begin{cases} \lambda, if\ \gamma \geq \dfrac{\beta(1-\tau-\omega k)}{\omega k} \\ \lambda, if\ \gamma < \dfrac{\beta(1-\tau-\omega k)}{\omega k}\ and\ \gamma \geq \dfrac{1-\omega}{\omega}\beta \\ s_{L,k}, if\ \ \gamma < \dfrac{\beta(1-\tau-\omega k)}{\omega k}\ and\ \gamma < \dfrac{1-\omega}{\omega}\beta \end{cases}$$

One can combine the two cases where $\lambda_{s,k}^{L*} = \lambda$ because

$$\frac{\beta(1-\tau-\omega k)}{\omega k} - \frac{1-\omega}{\omega}\beta = \frac{\beta(1-\tau-k)}{\omega k} > 0$$

And we have $\frac{\beta(1-\tau-\omega k)}{\omega k} > \frac{1-\omega}{\omega}\beta$. Therefore, $\lambda_{s,k}^{L*}$ can be described with

$$\lambda_{s,k}^{L*} = \begin{cases} \lambda, if\ \ \gamma \geq \dfrac{1-\omega}{\omega}\beta \\ s_{L,k}, if\ \gamma < \dfrac{1-\omega}{\omega}\beta \end{cases}$$

Next, let us compute $\lambda_{f,k}^{L*}$ and $\lambda_{f,k}^{H*}$.

Rearranging inequality (1) shows that it is equivalent to

$$(1-\omega)(\beta+\gamma)\left((1-\tau-k)\lambda_{s,k}^{H}+(1-\tau)\lambda_{s,k}^{L}\right) \geq \beta(1-\tau-h)(\lambda-\lambda_{f,k}^{L}) \qquad (1')$$

This leads to a lower bound for $\lambda_{f,k}^{L}$:

$$\lambda_{f,k}^{L} \geq \lambda - \frac{(1-\omega)(\beta+\gamma)\left((1-\tau-k)\lambda_{s,k}^{H}+(1-\tau)\lambda_{s,k}^{L}\right)}{\beta(1-\tau-h)}$$

Rearranging inequality (2) shows that it is equivalent to

$$\omega(\beta+\gamma)\left((1-\tau-k)\lambda_{s,k}^{H}+(1-\tau)\lambda_{s,k}^{L}\right) \geq \beta(1-\tau)\lambda_{f,k}^{L} \qquad (2')$$

Dividing $\beta(1-\tau)$ from both sides of $(2')$, and we have

$$\lambda_{f,k}^{L} \leq \frac{\omega(\beta+\gamma)\left((1-\tau-k)\lambda_{s,k}^{H}+(1-\tau)\lambda_{s,k}^{L}\right)}{\beta(1-\tau)}$$

Together with the budget constraints, we obtain the range

$$\lambda_{f,k}^{L} \geq \max\left\{\lambda - \frac{(1-\omega)(\beta+\gamma)\left((1-\tau-k)\lambda_{s,k}^{H}+(1-\tau)\lambda_{s,k}^{L}\right)}{\beta(1-\tau-h)}, 0\right\}$$

$$\lambda_{f,k}^{L} \leq \min\left\{\frac{\omega(\beta+\gamma)\left((1-\tau-k)\lambda_{s,k}^{H}+(1-\tau)\lambda_{s,k}^{L}\right)}{\beta(1-\tau)}, \lambda\right\}$$

When $\gamma \geq \frac{1-\omega}{\omega}\beta$, $\lambda_{s,k}^{L*}=\lambda$ and $\lambda_{s,k}^{H*}=0$. Substitute into this range, we obtain that

$$\max\left\{\lambda - \frac{(1-\omega)(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau-h)}, 0\right\} \leq \lambda_{f,k}^{L} \leq \min\left\{\frac{\omega(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau)}, \lambda\right\}$$

Since $\gamma \geq \frac{1-\omega}{\omega}\beta$, we have $\omega(\beta+\gamma) \geq \beta$, and

$$\frac{\omega(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau)} = \frac{\omega(\beta+\gamma)\lambda}{\beta} \geq \lambda$$

The lower bound for $\lambda_{f,k}^{L}$ is strictly less than λ. Because higher values of $\lambda_{f,k}^{L}$ results in higher tax savings, the optimal solution $\lambda_{f,k}^{L*}=\lambda$.

When $\gamma < \frac{1-\omega}{\omega}\beta$, substitute $\lambda_{s,k}^{L*}=s_L$ and $\lambda_{s,k}^{H*}=\lambda-s_{L,k}$ into the range of $\lambda_{f,k}^{L}$,

$$\lambda_{f,k}^{L} \geq \max\left\{\lambda - \frac{(1-\omega)(\beta+\gamma)\left((1-\tau-k)(\lambda-s_{L,k})+(1-\tau)s_{L,k}\right)}{\beta(1-\tau-h)}, 0\right\}$$

$$\lambda_{f,k}^{L} \leq \min\left\{\frac{\omega(\beta+\gamma)\left((1-\tau-k)(\lambda-s_{L,k})+(1-\tau)s_{L,k}\right)}{\beta(1-\tau)}, \lambda\right\}$$

Recall that inequality (4) is binding at $\lambda_{s,k}^{L} = s_{L,k}$. In other words, when $\lambda_{s,k}^{L} = s_{L,k}$, and $\lambda_{s,k}^{H} = \lambda - s_{L,k}$, inequality (4) becomes an equality, so we can write:

$$\omega(\beta+\gamma)\Big((1-\tau-k)\big(\lambda - s_{L,k}\big) + (1-\tau)s_{L,k}\Big) = \beta(1-\tau)s_{L,k}$$

Therefore, the ranges of $\lambda_{f,k}^{L}$ becomes

$$\lambda_{f,k}^{L} \geq \max\left\{\lambda - \frac{(1-\omega)\beta(1-\tau)s_{L,k}}{\omega\beta(1-\tau-h)}, 0\right\}$$

$$\lambda_{f,k}^{L} \leq \min\left\{\frac{\beta(1-\tau)s_{L,k}}{\beta(1-\tau)}, \lambda\right\} = \min\{s_{L,k}, \lambda\} = s_{L,k}$$

One can check that this range is non-empty by computing that the following difference is positive.

$$s_{L,k} - \left(\lambda - \frac{(1-\omega)\beta(1-\tau)s_{L,k}}{\omega\beta(1-\tau-h)}\right)$$

$$= \frac{(1-\tau)\Big(\big(1-\tau-k-\omega(h-k)\big)\gamma + \beta(1-\omega)(h-k)\Big)\lambda}{(\beta(1-\tau)-\omega(\beta+\gamma)k)(1-\tau-h)}$$

Now because

$$\gamma < \frac{1-\omega}{\omega}\beta < \frac{\beta(1-\tau-\omega k)}{\omega k}$$

we have $\beta(1-\tau)-\omega(\beta+\gamma)k > 0$. Furthermore,

$$1-\tau-k-\omega(h-k) \geq 1-\tau-k-(h-k) = 1-\tau-h > 0$$

Therefore, this difference is strictly positive, and the lower bound for $\lambda_{f,k}^{L}$ is strictly less than the upper bound $s_{L,k}$.

Again, higher values of $\lambda_{f,k}^{L}$ results in higher tax savings, so the optimal solution $\lambda_{f,k}^{L*} = s_{L,k}$ and $\lambda_{f,k}^{H*} = \lambda - s_{L,k}$. Note that inequality (2) is binding because $\lambda_{f,k}^{L*} = s_{L,k}$ takes the upper bound given by inequality (2). Furthermore, inequality (1) has slack because $s_{L,k}$ is strictly greater than the lower bound given by inequality (1).

After determining the optimal payoff for inducing collaboration on the innovative project, the headquarters compares it with the optimal payoff for not inducing it. This allows the headquarters to determine whether pursuing the innovative opportunity is worthwhile.

The optimal payoff for not inducing collaboration is $\beta(1-\tau)\lambda$. The headquarters compares this payoff with the optimal expected payoff for inducing collaboration as given in the two cases to the solution of (LP-2-S).

Case 1. $\gamma \geq \frac{1-\omega}{\omega}\beta$: the optimal allocation that induces collaboration is $\lambda_{f,k}^{L} = \lambda_{s,k}^{L} = \lambda$ and $\lambda_{f,k}^{H} = \lambda_{s,k}^{H} = 0$, and the optimal expected payoff associated is $p(\beta+\gamma)(1-\tau)\lambda + (1-p)\beta(1-\tau)\lambda$. Inducing collaboration in this case has a higher optimal payoff, as $p(\beta+\gamma)(1-\tau)\lambda + (1-p)\beta(1-\tau)\lambda > \beta(1-\tau)\lambda$, making it worthwhile.

Case 2. $\gamma < \frac{1-\omega}{\omega}\beta$: the optimal allocation that induces collaboration is $\lambda_{f,k}^{L} = \lambda_{s,k}^{L} = s_{L,k}$ and $\lambda_{f,k}^{H} = \lambda_{s,k}^{H} = \lambda - s_{L,k}$, and the optimal payoff associated with this allocation is

$$p(\beta+\gamma)\left((1-\tau-k)(\lambda-s_{L,k}) + (1-\tau)s_{L,k}\right)$$
$$+ (1-p)\beta\left((1-\tau-h)\big(\lambda-s_{L,k}\big) + (1-\tau)s_{L,k}\right)$$
$$= \frac{(1-\tau)\Big(\big((1-\tau-k)p + \omega(1-p)(h-k)\big)\gamma + (1-\tau-h+(h-k)(p+\omega(1-p)))\beta\Big)\beta\lambda}{\beta(1-\tau)-\omega(\beta+\gamma)k}$$

The difference between this payoff and that for not inducing collaboration is:

$$\frac{(1-\tau)\Big(\big((1-\tau-k)p + \omega(1-p)(h-k)\big)\gamma + (1-\tau-h+(h-k)(p+\omega(1-p)))\beta\Big)\beta\lambda}{\beta(1-\tau)-\omega(\beta+\gamma)k}$$
$$-\beta(1-\tau)\lambda$$
$$= \frac{\beta(1-\tau)\Big(\big(p(1-\tau-k)+\omega\big(h-p(h-k)\big)\big)\,\gamma - \beta(1-\omega)\big(h-p(h-k)\big)\Big)}{\beta(1-\tau)-\omega(\beta+\gamma)k}\lambda$$

When $\gamma < \frac{1-\omega}{\omega}\beta$, $(1-\tau)-\omega(\beta+\gamma)k > 0$, and the difference is positive if and only if

$$\big(p(1-\tau-k)+\omega\big(h-p(h-k)\big)\big)\,\gamma - \beta(1-\omega)\big(h-p(h-k)\big) > 0$$

that is equivalent to

$$\gamma > \frac{(1-\omega)\big(h-p(h-k)\big)}{p(1-\tau-k)+\omega\big(h-p(h-k)\big)}\beta$$

This lower bound of γ together with the upper bound that defines case 2 produces a range for γ.

One can check that the range is non-empty by computing the following.

$$\frac{1-\omega}{\omega}\beta-\frac{(1-\omega)\big(h-p(h-k)\big)}{p(1-\tau-k)+\omega\big(h-p(h-k)\big)}\beta=\frac{p(1-\omega)(1-\tau-k)}{\omega\Big(p(1-\tau-k)+\omega\big(h-p(h-k)\big)\Big)}\beta>0$$

Therefore, in case 2, inducing collaboration is worthwhile if and only if $\gamma > \frac{(1-\omega)(h-p(h-k))}{p(1-\tau-k)+\omega(h-p(h-k))}\beta$.

In summary, when $\gamma \geq \frac{1-\omega}{\omega}\beta$, first-best is obtained, and the headquarters induces collaboration with no additional tax cost. It maximizes tax savings by allocating $(\lambda_{s,k}^{H*}, \lambda_{s,k}^{L*}, \lambda_{f,k}^{H*}, \lambda_{f,k}^{L*}) = (0, \lambda, 0, \lambda)$.

When $\frac{(1-\omega)(h-p(h-k))}{p(1-\tau-k)+\omega(h-p(h-k))}\beta < \gamma < \frac{1-\omega}{\omega}\beta$, inducing collaboration has a tax cost, but its benefit outweighs the cost, and the optimal allocation induces collaboration at the lowest tax cost. The optimal allocation in this case is the optimal solution to (LP-2-S), that is $(\lambda_{s,k}^{H*}, \lambda_{s,k}^{L*}, \lambda_{f,k}^{H*}, \lambda_{f,k}^{L*}) = (\lambda - s_{L,k}, s_{L,k}, \lambda - s_{L,k}, s_{L,k})$.

Finally, when $\gamma < \frac{(1-\omega)(h-p(h-k))}{p(1-\tau-k)+\omega(h-p(h-k))}\beta$, inducing collaboration is not worthwhile, and the optimal allocation is $\lambda_k^{L*} = \lambda$ and $\lambda_k^{H*} = 0$. Note that this allocation does not refer to the prototype outcome, because the headquarters decides not to pursue the innovative opportunity.

Proof of Proposition 6.2

Comparing the optimal allocation before (Proposition 2.2) and after (Lemma 2.2) the specific rate reduction, we obtain the following cases.

First, when $\gamma > \frac{1-\omega}{\omega}\beta$, the first best allocation can be achieved, both before and after the general rate reduction, and in this case, $\lambda_{s,k}^{H*} = \lambda_{f,k}^{H*} = \lambda_s^{H*} = \lambda_f^{H*} = 0$.

Second, one can show that the inducing threshold after the specific rate reduction (in Lemma 2.2) is smaller than that before rate reduction (in Proposition 2.2) by computing the following.

$$\frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta - \frac{(1-\omega)(h-p(h-k))}{p(1-\tau-k)+\omega\big(h-p(h-k)\big)}\beta$$
$$= \frac{(p(1-\tau-h)+h)(1-\omega)(h-k)\beta}{\Big(p(1-\tau-k)+\omega\big(h-p(h-k)\big)\Big)(p(1-\tau-h)+\omega h)} > 0$$

Therefore, the inducing threshold decreases from $\frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta$ to $\frac{(1-\omega)(h-p(h-k))}{p(1-\tau-k)+\omega(h-p(h-k))}\beta$ after the specific tax rate reduction. This results in two subcases.

First, when $\gamma < \frac{(1-\omega)(h-p(h-k))}{p(1-\tau-k)+\omega(h-p(h-k))}\beta$, inducing collaboration is not worthwhile before the tax cut and is still not worthwhile after the tax cut, and in this case, $\lambda_k^{H*} = \lambda^{H*} = 0$.

Second, when $\frac{(1-\omega)(h-p(h-k))}{p(1-\tau-k)+\omega(h-p(h-k))}\beta < \gamma < \frac{(1-\omega)h}{p(1-\tau-h)+\omega h}\beta$, inducing collaboration becomes worthwhile only after the tax cut, and in this case,

$$\lambda^{H*} = 0 < \lambda_{s,k}^{H*} = \lambda_{f,k}^{H*} = \lambda - s_{L,k}$$

In the final case, when $\frac{(1-\omega)h}{p(1-\tau-k)+\omega h}\beta < \gamma < \frac{1-\omega}{\omega}\beta$, inducing collaboration is worthwhile both before and after the tax cut. The optimal allocations are: $\lambda_s^{H*} = \lambda_f^{H*} = \lambda - s_L$ and $\lambda_{s,k}^{H*} = \lambda_{f,k}^{H*} = \lambda - s_{L,k}$.

Comparing these two values, one sees that

$$\lambda_s^{H*} - \lambda_{s,k}^{H*} = s_{L,k} - s_L = \frac{\omega(\beta+\gamma)(1-\tau)(h-k)(\beta-\omega(\beta+\gamma))\lambda}{(\beta(1-\tau)-\omega(\beta+\gamma)k)(\beta(1-\tau)-\omega(\beta+\gamma)h)}$$

Now, because $\gamma < \frac{1-\omega}{\omega}\beta$, we have $\beta > \omega(\beta+\gamma)$ and

$$\beta(1-\tau) - \omega(\beta+\gamma)k > \beta(1-\tau-k) > 0$$

$$\beta(1-\tau) - \omega(\beta+\gamma)h > \beta(1-\tau-h) > 0$$

Therefore, $\lambda_s^{H*} = \lambda_f^{H*} > \lambda_{s,k}^{H*} = \lambda_{f,k}^{H*}$.

Proof of Lemma 2.4

The specific rate reduction applies to the innovative project but not to the traditional one, so the problem can be reformulated with LP-4-S. Solving this LP gives the optimal allocation if the HQ chooses to induce collaboration.

$$\max_{\lambda^H_{s,I,k},\lambda^L_{s,I,k},\lambda^H_{s,T,k},\lambda^L_{s,T,k},\lambda^H_{f,k},\lambda^L_{f,k}} p(\beta+\gamma)\left((1-\tau-k)\lambda^H_{s,I,k}+(1-\tau)\lambda^L_{s,I,k}\right)$$

$$+(1-p)\beta\left((1-\tau-h)\lambda^H_{f,k}+(1-\tau)\lambda^L_{f,k}\right)$$

Subject to.

$$p(1-\omega)(\beta+\gamma)\left((1-\tau-k)\lambda^H_{s,I,k}+(1-\tau)\lambda^L_{s,I,k}\right)+(1-p)\beta(1-\tau-h)\lambda^H_{f,k}$$

$$\geq \beta(1-\tau-h)\lambda^H_{f,k} \qquad (1)$$

$$p\omega(\beta+\gamma)\left((1-\tau-k)\lambda^H_{s,I,k}+(1-\tau)\lambda^L_{s,I,k}\right)+(1-p)\beta(1-\tau)\lambda^L_{f,k}\geq \beta(1-\tau)\lambda^L_{f,k} \qquad (2)$$

$$(1-\omega)(\beta+\gamma)\left((1-\tau-k)\lambda^H_{s,I,k}+(1-\tau)\lambda^L_{s,I,k}\right)\geq \beta(1-\tau-h)\lambda^H_{s,T,k} \qquad (3)$$

$$\omega(\beta+\gamma)\left((1-\tau-k)\lambda^H_{s,I,k}+(1-\tau)\lambda^L_{s,I,k}\right)\geq \beta(1-\tau)\lambda^L_{s,T,k} \qquad (4)$$

$$\lambda^H_{s,I,k}+\lambda^L_{s,I,k}\leq \lambda \qquad (5)$$

$$\lambda^H_{s,T,k}+\lambda^L_{s,T,k}\leq \lambda \qquad (6)$$

$$\lambda^H_{f,k}+\lambda^L_{f,k}\leq \lambda \qquad (7)$$

$$\lambda^H_{s,I,k},\lambda^L_{s,I,k},\lambda^H_{s,T,k},\lambda^L_{s,T,k},\lambda^H_{f,k},\lambda^L_{f,k}\geq 0 \qquad (8)$$

For the same reason as outlined in the proof of Proposition 4, the proof below takes the budget constraint at equality.

Take any feasible allocation $(\lambda^H_{s,I,k},\lambda^L_{s,I,k},\lambda^H_{s,T,k},\lambda^L_{s,T,k},\lambda^H_{f,k},\lambda^L_{f,k})$, we first show that the allocation $(0,\lambda,\lambda^H_{s,T,k},\lambda^L_{s,T,k},\lambda^H_{f,k},\lambda^L_{f,k})$ is also feasible. One can verify that the left-hand side of inequalities (1) to (4) are increasing in $\lambda^L_{s,I,k}$ while the right-hand side does not depend on $\lambda^L_{s,I,k}$. Therefore, if

$\lambda_{s,I,k}^{L}$ increases to λ, the left-hand side is greater while the right-hand remains unchanged, and thus still satisfies inequalities (1) to (4).

Furthermore, the feasible solution $(0, \lambda, \lambda_{s,T,k}^{H}, \lambda_{s,T,k}^{L}, \lambda_{f,k}^{H}, \lambda_{f,k}^{L})$ produces a larger objective value than $(\lambda_{s,I,k}^{H}, \lambda_{s,I,k}^{L}, \lambda_{s,T,k}^{H}, \lambda_{s,T,k}^{L}, \lambda_{f,k}^{H}, \lambda_{f,k}^{L})$, because the objective value is increasing in $\lambda_{s,I,k}^{L}$. Therefore, the optimal solution must have $\lambda_{s,I,k}^{H*} = 0$ and $\lambda_{s,I,k}^{L*} = \lambda$.

Next, let us solve for the feasible range for $\lambda_{s,T,k}^{H}$ and $\lambda_{s,T,k}^{L}$. Substitute $\lambda_{s,I,k}^{H*} = 0$ and $\lambda_{s,I,k}^{L*} = \lambda$ into inequalities (3) and (4). Solving (4) provides the following upper bound for $\lambda_{s,T,k}^{L}$:

$$\lambda_{s,T,k}^{L} \leq \frac{\omega(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau)} = \frac{\omega(\beta+\gamma)}{\beta}\lambda$$

Furthermore, by the budget constraint, we can substitute $\lambda_{s,T,k}^{H} = \lambda - \lambda_{s,T,k}^{L}$ into inequality (3) to solve for a lower bound for $\lambda_{s,T,k}^{L}$:

$$\lambda_{s,T,k}^{L} \geq \lambda - \frac{(1-\omega)(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau-h)}$$

Furthermore, the budget constraint requires that $0 \leq \lambda_{s,T,k}^{L} \leq \lambda$. Therefore, the range of $\lambda_{s,T,k}^{L}$ has a lower bound of $\max\left\{0, \lambda - \frac{(1-\omega)(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau-h)}\right\}$ and an upper bound of $\min\left\{\frac{\omega(\beta+\gamma)}{\beta}\lambda, \lambda\right\}$. This range for $\lambda_{s,T,k}^{L}$ is non-empty because first, it is clear that

$$\lambda - \frac{(1-\omega)(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau-h)} < \lambda$$

and second,

$$\lambda - \frac{(1-\omega)(\beta+\gamma)\big((1-\tau-h)\lambda + h\lambda\big)}{\beta(1-\tau-h)} < \frac{\omega(\beta+\gamma)}{\beta}\lambda$$

that is equivalent to showing

$$\frac{\omega(\beta+\gamma)}{\beta}\lambda - \left(\lambda - \frac{(1-\omega)(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau-h)}\right) = \frac{\gamma(1-\tau-\omega h) + \beta h(1-\omega)}{\beta(1-\tau-h)} > 0$$

Therefore, we obtain a feasible range for $\lambda_{s,T,k}^{L}$:

$$\max\left\{0, \lambda - \frac{(1-\omega)(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau-h)}\right\} \leq \lambda_{s,T,k}^{L} \leq \min\left\{\frac{\omega(\beta+\gamma)}{\beta}\lambda, \lambda\right\}$$

When $\gamma \geq \frac{1-\omega}{\omega}\beta$, $\frac{\omega(\beta+\gamma)}{\beta}\lambda \geq \lambda$, this range becomes

$$\max\left\{0, \lambda - \frac{(1-\omega)(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau-h)}\right\} \leq \lambda_{s,T,k}^{L} \leq \lambda$$

When $\gamma < \frac{1-\omega}{\omega}\beta$, $\frac{\omega(\beta+\gamma)}{\beta}\lambda < \lambda$, this range becomes

$$\max\left\{0, \lambda - \frac{(1-\omega)(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau-h)}\right\} \leq \lambda_{s,T,k}^{L} \leq \frac{\omega(\beta+\gamma)}{\beta}\lambda$$

One can compute the feasible range for $\lambda_{s,T,k}^{H}$ by substituting $\lambda_{s,T,k}^{L} = \lambda - \lambda_{s,T,k}^{H}$. Because the objective function does not refer to $\lambda_{s,T,k}^{H}, \lambda_{s,T,k}^{L}$, the optimal solution can take any value of $\lambda_{s,T,k}^{H}, \lambda_{s,T,k}^{L}$ within the feasible range.

Finally, we solve for the optimal value for $\lambda_{f,k}^{H}$ and $\lambda_{f,k}^{L}$. Substitute $\lambda_{s,I,k}^{H*} = 0$ and $\lambda_{s,I,k}^{L*} = \lambda$ into inequalities (1) and (2). Solving (2) provides the following upper bound for $\lambda_{f,k}^{L}$:

$$\lambda_{f,k}^{L} \leq \frac{\omega(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau)} = \frac{\omega(\beta+\gamma)}{\beta}\lambda$$

Furthermore, by the budget constraint, we can substitute $\lambda_{f,k}^{H} = \lambda - \lambda_{f,k}^{L}$ into inequality (1) to solve for a lower bound for $\lambda_{f.k}^{L}$:

$$\lambda_{f,k}^{L} \geq \lambda - \frac{(1-\omega)(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau-h)}$$

Furthermore, the budget constraint requires that $0 \leq \lambda_{f,k}^{L} \leq \lambda$. Therefore, the range of $\lambda_{f,k}^{L}$ has a lower bound of $\max\left\{0, \lambda - \frac{(1-\omega)(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau-h)}\right\}$ and an upper bound of $\min\left\{\frac{\omega(\beta+\gamma)}{\beta}\lambda, \lambda\right\}$. This range is non-empty, because first, it is clear that

$$\lambda - \frac{(1-\omega)(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau-h)} < \lambda$$

and second,

$$\lambda - \frac{(1-\omega)(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau-h)} < \frac{\omega(\beta+\gamma)}{\beta}\lambda$$

that is equivalent to showing

$$\frac{\omega(\beta+\gamma)}{\beta}\lambda - \left(\lambda - \frac{(1-\omega)(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau-h)}\right) = \frac{\gamma(1-\tau-\omega h)+\beta h(1-\omega)}{\beta(1-\tau-h)} > 0$$

Therefore, the feasible range of $\lambda_{f,k}^{L}$ is:

$$\max\left\{0, \lambda - \frac{(1-\omega)(\beta+\gamma)(1-\tau)\lambda}{\beta(1-\tau-h)}\right\} \leq \lambda_{f,k}^{L} \leq \min\left\{\frac{\omega(\beta+\gamma)}{\beta}\lambda, \lambda\right\}$$

Now, because the objective value is increasing in $\lambda_{f,k}^{L}$, the optimal solution $\lambda_{f,k}^{L*}$ must take the upper bound.

$$\lambda_{f,k}^{L*} = \min\left\{\frac{\omega(\beta+\gamma)}{\beta}\lambda, \lambda\right\}$$

When $\gamma \geq \frac{1-\omega}{\omega}\beta$, $\frac{\omega(\beta+\gamma)}{\beta}\lambda \geq \lambda$, we have $\lambda_{f,k}^{L*} = \lambda$ and $\lambda_{f,k}^{H*} = 0$, and the optimal solution is $\left(\lambda_{s,I,k}^{H}, \lambda_{s,I,k}^{L}, \lambda_{s,T,k}^{H}, \lambda_{s,T,k}^{L}, \lambda_{f,k}^{H}, \lambda_{f,k}^{L}\right) = \left(0, \lambda, \lambda_{s,T,k}^{H*}, \lambda_{s,T,k}^{L*}, 0, \lambda\right)$, where $\lambda_{s,T,k}^{H*}$ and $\lambda_{s,T,k}^{L*}$ can take any value within the feasible range. Note that this corresponds to the first best scenario in the previous models.

When $\gamma < \frac{1-\omega}{\omega}\beta$, $\frac{\omega(\beta+\gamma)}{\beta}\lambda < \lambda$, we have $\lambda_{f,k}^{L*} = \frac{\omega(\beta+\gamma)}{\beta}\lambda$ and $\lambda_{f,k}^{H*} = \lambda - \frac{\omega(\beta+\gamma)}{\beta}\lambda$, and the optimal solution is

$$\left(\lambda_{s,I,k}^{H}, \lambda_{s,I,k}^{L}, \lambda_{s,T,k}^{H}, \lambda_{s,T,k}^{L}, \lambda_{f,k}^{H}, \lambda_{f,k}^{L}\right) = \left(0, \lambda, \lambda_{s,T,k}^{H*}, \lambda_{s,T,k}^{L*}, \lambda - \frac{\omega(\beta+\gamma)}{\beta}\lambda, \frac{\omega(\beta+\gamma)}{\beta}\lambda\right)$$

where $\lambda_{s,T,k}^{H*}$ and $\lambda_{s,T,k}^{L*}$ can take any value within the feasible range. Note that the tax minimizing allocation can be specified only for the success outcome but not for the failure outcome. Hence, this solution is not the first best.

Proof of Proposition 6.4

The specific rate reduction does not change the allocation. One can see that the optimal allocation for model 4 is the same before and after the specific rate reduction by observing that Lemma 2.4 yields the same result as Proposition 2.4.